THE SILVICULTURE
OF
INDIAN TREES

VOLUME I
Dilleniaceae to Leguminosae (Papilionaceae)

OXFORD UNIVERSITY PRESS
LONDON EDINBURGH GLASGOW NEW YORK
TORONTO MELBOURNE CAPE TOWN BOMBAY
HUMPHREY MILFORD
PUBLISHER TO THE UNIVERSITY

28397. M.26

THE SILVICULTURE
OF
INDIAN TREES

TPL
STOCK VERI
1995

BY

R. S. TROUP, M.A., C.I.E.

INDIAN FOREST SERVICE; FELLOW OF ST. JOHN'S COLLEGE, OXFORD, AND
PROFESSOR OF FORESTRY IN THE UNIVERSITY

VOLUME I

Dilleniaceae to Leguminosae (Papilionaceae)

PUBLISHED UNDER THE AUTHORITY OF HIS MAJESTY'S
SECRETARY OF STATE FOR INDIA IN COUNCIL

OXFORD
AT THE CLARENDON PRESS
1921

CONTENTS OF VOLUME I

PAGE

LIST OF ILLUSTRATIONS vii

INTRODUCTION xi

ORDER I. DILLENIACEAE 1
Dillenia, p. 1.

ORDER II. MAGNOLIACEAE 4
Michelia, p. 4.

ORDER III. ANONACEAE 8
1. Miliusa, p. 8 ; 2. Saccopetalum, p. 9 ; 3. Canangium, p. 9 ; 4. Polyalthia, p. 10.

ORDER IV. CAPPARIDACEAE 10
1. Crataeva, p. 10 ; 2. Capparis, p. 12.

ORDER V. BIXACEAE 12
1. Cochlospermum, p. 12 ; 2. Flacourtia, p. 12 ; 3. Hydnocarpus, p. 13 ; 4. Taraktogenos, p. 15.

ORDER VI. TAMARICACEAE 15
Tamarix, p. 15.

ORDER VII. GUTTIFERAE 20
1. Calophyllum, p. 21 ; 2. Poeciloneuron, p. 22 ; 3. Mesua, p. 23.

ORDER VIII. TERNSTROEMIACEAE 29
Schima, p. 29.

ORDER IX. DIPTEROCARPACEAE 30
1. Dipterocarpus, p. 35 ; 2. Hopea, p. 47 ; 3. Pentacme, p. 53 ; 4. Shorea, p. 55 ; 5. Parashorea, p. 134 ; 6. Balanocarpus, p. 134 ; 7. Vateria, p. 134.

ORDER X. MALVACEAE 135
1. Bombax, p. 135 ; 2. Kydia, p. 146 ; 3. Thespesia, p. 150 ; 4. Eriodendron, p. 150 ; 5. Adansonia, p. 151 ; 6. Durio, p. 151 ; 7. Cullenia, p. 151.

ORDER XI. STERCULIACEAE 151
1. Sterculia, p. 151 ; 2. Heritiera, p. 153 ; 3. Pterospermum, p. 160 ; 4. Helicteres, p. 162.

ORDER XII. TILIACEAE 162
1. Pentace, p. 162 ; 2. Berrya, p. 162 ; 3. Grewia, p. 164 ; 4. Echinocarpus, p. 166.

PAGE

ORDER XIII. RUTACEAE 166
Aegle, p. 167.

ORDER XIV. SIMARUBACEAE 171
Ailanthus, p. 171.

ORDER XV. BURSERACEAE 174
1. Boswellia, p. 174 ; 2. Garuga, p. 176.

ORDER XVI. MELIACEAE 178
1. Azadirachta, p. 178 ; 2. Melia, p. 183 ; 3. Carapa, p. 186 ; 4. Soymida, p. 187 ; 5. Chickrassia, p. 191 ; 6. Cedrela, p. 194 ; 7. Chloroxylon, p. 200 ; 8. Dysoxylum, p. 204 ; 9. Sandoricum, p. 204 ; 10. Amoora, p. 205 ; 11. Swietenia, p. 205.

ORDER XVII. ILICINEAE 209
Ilex, p. 209.

ORDER XVIII. CELASTRACEAE 209
1. Lophopetalum, p. 209 ; 2. Elaeodendron, p. 210.

ORDER XIX. RHAMNACEAE 211
Zizyphus, p. 211.

ORDER XX. SAPINDACEAE 221
1. Acer, p. 221 ; 2. Dodonaea, p. 225 ; 3. Aesculus, p. 226 ; 4. Schleichera, p. 229 ; 5. Sapindus, p. 232.

ORDER XXI. ANACARDIACEAE 235
1. Rhus, p. 235 ; 2. Pistacia, p. 235 ; 3. Semecarpus, p. 236 ; 4. Anacardium, p. 237 ; 5. Mangifera, p. 237 ; 6. Bouea, p. 240 ; 7. Buchanania, p. 240 ; 8. Melanorrhoea, p. 243 ; 9. Odina, p. 245 ; 10. Spondias, p. 246.

ORDER XXII. MORINGACEAE 249
Moringa, p. 249.

ORDER XXIII. LEGUMINOSAE 250

SUB-ORDER I. PAPILIONACEAE 252
1. Ougeinia, p. 253 ; 2. Butea, p. 257 ; 3. Erythrina, p. 264 ; 4. Pterocarpus, p. 265 ; 5. Dalbergia, p. 294 ; 6. Pongamia, p. 331 ; 7. Robinia, p. 332.

INDEX TO SCIENTIFIC NAMES, VOLUME I.

LIST OF ILLUSTRATIONS, VOLUME I

PAGE
Rainfall map of India *Frontispiece*
1. *Dillenia indica*, seedling 2
2. *Dillenia pentagyna*, girth 8 ft. 6 in., Buxa district, Bengal. (Author photo.) 6
3. *Michelia excelsa*, girth 9 ft. 3 in., height about 110 ft., clear bole about 75 ft., Darjeeling hills. (H. S. Gibson photo.) 6
4. *Michelia excelsa*, pole crop about twenty years old, normally developed, Darjeeling hills. (H. S. Gibson photo.) 6
5. *Michelia excelsa*, pole crop about twenty years old, stunted owing to excess of moisture in the soil, Darjeeling hills; trees in flower. (H. S. Gibson photo.) 6
6. *Michelia Champaca* in evergreen forest, Bengal Duars, girth 8 ft. 9 in., height 110 ft. (Author photo.) 7
7. *Crataeva religiosa*, seedling 10
8. *Hydnocarpus Wightiana*, seedling 14
9. *Mesua ferrea*, seedling 24
10. *Dipterocarpus indicus*, seedling 38
11. *Dipterocarpus tuberculatus*, large trees in open forest with soil-covering of coarse grass, Katha, Upper Burma. (Author photo.) 44
12. *Dipterocarpus tuberculatus*, profuse natural reproduction, Burma. (A. Rodger photo.) 44
13. *Dipterocarpus alatus*, 18 ft. in girth, Magayi reserve, Insein forest division, Burma. (J. H. Lace photo.) 45
14. *Hopea parviflora*, seedling 50
15. Teak plantation with natural underwood of *Hopea parviflora*, South Malabar. (E. Marsden photo.) 52
16. *Pentacme suavis*, trees in semi-*indaing* forest of good quality, Mongmit state, Upper Burma. (J. W. Oliver photo.) 53
17. *Shorea robusta*, dense even-aged pole crop, Dehra Dun, United Provinces 60
18. *Shorea robusta* pole forest along edge of grassy blank, in which natural reproduction is gradually appearing, Dehra Dun. (Author photo.) 61
19. *Shorea robusta*, dense pole crop sprung from isolated seed-bea[illegible]s on a grassy plain, Patli Dun, United Provinces. (Author photo.) 61
20. *Shorea robusta* forest of poor quality on stiff clay, Gorakhpur, United Provinces. (Author photo.) 62
21. *Shorea robusta*, fire-protected *chandar* in April, with thick growth of *ulla* grass (*Anthistiria gigantea*), Pilibhit, United Provinces. (T. B. Chitrakar photo.) 63
22. *Shorea robusta*, burnt *chandar* in April, showing dead sal shoots of previous year and new leafy shoots of current year appearing, Pilibhit, United Provinces. (T. B. Chitrakar photo.) 64
23. *Shorea robusta* mature forest of good quality, high-level type, North Kheri forests, United Provinces. (Author photo.) 65
24. *Shorea robusta* open forest of low-level type with soil-covering of grass, chiefly *Saccharum Narenga*, and no reproduction, North Kheri forests, United Provinces. (Author photo.) 65
25. *Shorea robusta* forest of *phanta*-belt type, showing absence of grass where stocking is dense, North Kheri forests, United Provinces. (Author photo.) 66
26. *Shorea robusta* poor open type of forest, Pilibhit, United Provinces. (T. B. Chitrakar photo.) 67
27. *Shorea robusta* high-level forest of the Duars, with dense undergrowth of *sau* grass (*Pollinia ciliata*), and *Millettia auriculata* also plentiful, Buxa, Bengal. (Author photo.) 68
28. *Shorea robusta* dry deciduous type of forest in the *bhabar* tract of Goalpara, Assam, sal mixed chiefly with *Lagerstroemia parviflora*. (Author photo.) 69

PAGE

29. *Shorea robusta* forest of best quality, just thinned, Jalpaiguri, **Bengal.** **(Author** photo.) . . . 70
30. *Shorea robusta* low-level forest of good quality, with fire-line, Goalpara, **Assam.** **(Author** photo.) . . . 71
31. Burnt savannah with young sal (*Shorea robusta*) gradually **establishing itself in spite of** fire, Goalpara, Assam. (Author photo.) . . . 72
32. *Shorea robusta*, young growth established in savannah burnt annually, **Buxa, Bengal.** (Author photo.) . . . 73
33. *Shorea robusta*, pole crop established in burnt savannah, Goalpara, **Assam.** **(Author** photo.) . . . 74
34. *Shorea robusta* forest with invasive evergreen undergrowth, chiefly *Alpinia*, **induced by** continued fire-protection, Jalpaiguri, Bengal. (Author photo.) . . . 75
35. *Shorea robusta* forest with invasive evergreen undergrowth, chiefly ***Phlogacanthus thyrsiflorus***, induced by continued fire-protection, Jalpaiguri, Bengal. **(Author photo.)** . 76
36. *Shorea robusta* forest with invasive evergreen undergrowth, **largely canes, induced by** continued fire-protection, Jalpaiguri, Bengal. (Author photo.) . . . 77
37. *Shorea robusta*, flowers. (T. B. Chitrakar photo.) . . . 78
38. *Shorea robusta*, fruits. (T. B Chitrakar photo.) . . . 78
39. *Shorea robusta*, tree in flower. (T. B. Chitrakar photo.) . . . 79
40. *Shorea robusta*, seedling . . . 80
41. *Shorea robusta*, vigorous clump of seedling plants three and a half years old, **just thinned** out, Mendabari, Buxa, Bengal. (Author photo.) . . . 86
42. *Shorea robusta*, coppice-with-standards coupe in which the coppice has failed owing to the felled trees having suffered from drought two years previously, Gorakhpur, United Provinces. (T. B. Chitrakar photo.) . . . 87
43. *Shorea robusta* forest killed by severe drought of 1907 and 1908, South Kheri, United Provinces. (Author photo.) . . . 90
44. *Shorea robusta* root-stock produced on *chandar* land, Pilibhit, United Provinces. (T. B. Chitrakar photo.) . . . 90
45. *Shorea robusta*, standards killed in coppice-with-standards by the abnormal drought of 1907 and 1908, Gonda, United Provinces. (T. B. Chitrakar photo.) . . . 91
46. *Shorea robusta*, effect of damage by frost, Lansdowne division, United Provinces . . 96
47. *Shorea robusta* moist forest opened out and burnt with the view of inducing a growth of grass and effecting natural reproduction of sal, but actually resulting in a dense growth of *Macaranga* and *Alpinia*, Buxa division, Bengal. (Author photo.) . . 97
48. *Shorea robusta*, experimental seeding felling in moist forest, the overwood being opened out and undergrowth cut and burnt, resulting not in sal reproduction but in a dense mass of weeds and climbers, Goalpara, Assam. (Author photo.) . . . 98
49. *Shorea robusta*, dense mass of natural reproduction under *Macaranga denticulata*, Jalpaiguri. **Bengal.** (Author photo.) . . . 99
50. *Shorea robusta*, plantation, Gorakhpur, United Provinces. (E. Marsden photo.) . . 108
51. *Shorea robusta*, coppice-with-standards immediately after cutting of coppice, Tikri forest, Gonda, United Provinces. (T. B. Chitrakar photo.) . . . 109
52. *Shorea robusta*, coppice-with-standards, coppice one year old, West Lehra forest, Gorakhpur, United Provinces. (T. B. Chitrakar photo.) . . . 110
53. *Shorea robusta*, coppice-with standards, coppice two years old, West Lehra forest, Gorakhpur, United Provinces. (T. B. Chitrakar photo.) . . . 111
54. *Shorea robusta*, coppice-with-standards, coppice eight years old. West Lehra forest, Gorakhpur, United Provinces. (T. B. Chitrakar photo.) . . . 112
55. *Shorea robusta*, coppice-with-standards, coppice twenty years old about to be cut, Tikri forest, Gonda, United Provinces. (T. B. Chitrakar photo.) . . . 113
56. *Shorea robusta* forest worked under concentrated regeneration fellings, immediately before final removal of overwood, young even-aged crop well established, Thano forest, Dehra Dun. (E. Marsden photo.) . . . 116
57. *Shorea robusta* forest worked under concentrated regeneration fellings, young crop two years after final removal of overwood, Thano forest, Dehra Dun. (E. Marsden photo.) 117

PAGE

58. *Shorea Tumbuggaia* at 2,500 ft. elevation on the Seshachellam hills, South Cuddapah, Madras, with undergrowth of *Phoenix humilis*. (E. Marsden photo.) . . . 132
59. *Shorea Talura* in Pikkilikona valley, Seshachellam hills, South Cuddapah, Madras. (E. Marsden photo.) . . . 133
60. *Bombax malabaricum*, seedling . . . 138
61. *Bombax malabaricum*, young trees establishing themselves under the protection of a dense growth of *Zizyphus Jujuba* on heavily grazed land, Dehra Dun, United Provinces. (Author photo.) . . . 140
62. *Bombax malabaricum*, trees growing gregariously on alluvial land, Dehra Dun, United Provinces. (Author photo.) . . . 141
63. *Bombax malabaricum*, irrigated weeded line sowings, end of fourth season, Dehra Dun, United Provinces. (T. B. Chitrakar photo.) . . . 142
64. *Heritiera Fomes* pure forest after a thinning, Sundarbans. (J. R. P. Gent photo.) . 143
65. *Kydia calycina*, seedling . . . 148
66. *Heritiera Fomes*, seedling . . . 156
67. *Pterospermum acerifolium*, seedling . . . 160
68. *Aegle Marmelos*, Dehra Dun, United Provinces. (T. B. Chitrakar photo.) . . . 166
69. *Aegle Marmelos*, growing gregariously on stiff clay soil, Bahraich, United Provinces. (Author photo.) . . . 167
70. *Boswellia serrata*. (E. Marsden photo.) . . . 167
71. *Aegle Marmelos*, seedling . . . 169
72. *Ailanthus excelsa*, seedling . . . 172
73. *Garuga pinnata*, Dehra Dun, United Provinces. (T. B. Chitrakar photo.) . . . 176
74. *Cedrela Toona*, Dehra Dun, United Provinces. (T. B. Chitrakar photo.) . . . 177
75. *Azadirachta indica*, seedling . . . 178
76. *Melia Azedarach*, seedling . . . 184
77. *Carapa moluccensis*, seedling . . . 186
78. *Soymida febrifuga*, seedling . . . 189
79. *Chickrassia tabularis*, seedling . . . 192
80. *Cedrela Toona*, seedling . . . 196
81. *Cedrela Toona*, natural reproduction, 10–14 ft. high, sprung up on cultivation abandoned three years previously, Buxa Duars, Bengal. (Author photo.) . . . 198
82. *Cedrela serrata* in flower, Kagan valley, Hazara. (Author photo.) . . . 199
83. *Chloroxylon Swietenia*, Belgaum district, Bombay. (E. M. Hodgson photo.) . . 200
84. *Zizyphus Jujuba* pure forest on alluvial sand and shingle, Siwaliks, United Provinces. (Author photo.) . . . 201
85. *Zizyphus Xylopyrus*, Siwaliks, United Provinces. (Author photo.) . . . 201
86. *Chloroxylon Swietenia*, seedling . . . 202
87. *Zizyphus Jujuba*, seedling . . . 212
88. *Zizyphus Xylopyrus*, seedling . . . 217
89. *Zizyphus vulgaris*, tree with dense growth of root-suckers, Hazara, 4,000 ft. (Author photo.) . . . 220
90. *Aesculus indica*, growing gregariously in a moist ravine, 7,500 ft., Kagan valley, Hazara. (Author photo.) . . . 220
91. *Acer caesium*, growing gregariously in an open glade at 8,000 ft., Hazara. (Author photo.) . . . 221
92. *Schleichera trijuga* trees, Siwaliks, United Provinces. (Author photo.) . . . 221
93. *Acer caesium*, seedling . . . 224
94. *Aesculus indica*, seedling . . . 226
95. *Schleichera trijuga*, seedling . . . 230
96. *Sapindus detergens*, seedling . . . 234
97. *Mangifera indica*, Dehra Dun, United Provinces. (T. B. Chitrakar photo.) . . . 236
98. *Odina Wodier*, Dehra Dun, United Provinces. (T. B. Chitrakar photo.) . . . 237
99. *Mangifera indica*, seedling . . . 239
100. *Buchanania latifolia*, seedling . . . 240
101. *Melanorrhoea usitata*, seedling . . . 244

PAGE
102. *Spondias mangifera*, seedling 248
103. *Ougeinia dalbergioides*, seedling 254
104. *Butea frondosa*, seedling 258
105. *Butea frondosa*, irrigated line sowings six months old, Dehra Dun. (T. B. Chitrakar photo.) 260
106. *Butea frondosa*, line sowings with the aid of field crops, Dehra Dun. (T. B. Chitrakar photo.) 260
107. *Butea frondosa*, irrigated line sowings three and a half years old, Dehra Dun. (T. B. Chitrakar photo.) 261
108. *Pterocarpus Marsupium*, seedling 268
109. *Pterocarpus santalinus*, forest in South Cuddapah. (E. Marsden photo.) 272
110. *Pterocarpus santalinus*, plantation of 1865 at Kodur, South Cuddapah, age fifty-two years. (E. Marsden photo.) 273
111. *Pterocarpus santalinus*, seedling 274
112. *Pterocarpus dalbergioides*, Andamans 278
113. *Pterocarpus dalbergioides* in semi-evergreen forest, Andamans 278
114. *Pterocarpus dalbergioides*, seedling 280
115. *Pterocarpus macrocarpus*, seedling 291
116. *Pterocarpus indicus*, seedling 292
117–121. *Dalbergia Sissoo*, development of natural riverain crops on alluvial gravel, Ramganga river, United Provinces. (Author photo.) 294, 295
122. *Dalbergia Sissoo*, seedling 296
123. *Dalbergia Sissoo*, pole crop on elevated river-bank subject to erosion, Dehra Dun, United Provinces. (Author photo.) 298
124. Riverain forest of *Dalbergia Sissoo* and other species killed by excessive deposits of silt, Raidak river, Buxa, Bengal. (Author photo.) 299
125. *Dalbergia Sissoo*, unirrigated line sowings with the aid of field crops, Dehra Dun. (T. B. Chitrakar photo.) 306
126. Changa Manga plantation: irrigated line sowings of sissoo eight months old. (E. Marsden photo.) 307
127. Kot Lakhpat plantation: irrigated line sowings of sissoo two years old. (E. Marsden photo.) 308
128. Changa Manga plantation: coupe recently felled, showing sissoo standards left and felling refuse on the ground. (B. O. Coventry photo.) 309
129. Changa Manga plantation: coupe showing sissoo standards and coppice six months old. (B. O. Coventry photo.) 310
130. Changa Manga plantation: sissoo standards over mulberry coppice sixteen years old. (E. Marsden photo.) 311
131. *Dalbergia latifolia*, Bombay Presidency. (R. S. Pearson photo.) 318
132. *Dalbergia latifolia*, seedling five months old, Dehra Dun. (T. B. Chitrakar photo.) 318
133. *Dalbergia latifolia*, seedling 320
134. *Dalbergia cultrata*, seedling 328
135. *Dalbergia Oliveri*, seedling 330
136. *Pongamia glabra*, seedling 332

INTRODUCTION

SCOPE OF PRESENT WORK. This work is the outcome of several years of research into silvicultural problems at the Forest Research Institute, Dehra Dun, and at outlying experimental stations, combined with observations recorded in many parts of India and Burma for a period extending over more than twenty years. My original intention was to publish, in the form of detached notes, only the results of my own investigations, confining my attention to a limited number of the more important forest trees. I was soon convinced, however, that a more useful purpose would be served by including all trees, whether of special importance or not, which have received even slight study from a silvicultural point of view, adding to the results of my own investigations those recorded from time to time by others. Such a course will enable future workers who may undertake the study of any particular species of tree to ascertain what information is already available regarding it and to pursue their investigations along fresh lines. The importance of silvicultural research is now more fully realized in India than it was at one time, and in future years great development in research methods and in our knowledge of the various trees may be anticipated. In a vast country like India, with an infinite variety of climates and forest types and a rich array of tree species, the different species cannot be studied fully except in their own habitat, for which purpose decentralization of work will be essential before any appreciable progress is made. From this point of view the present work may be regarded as nothing more than an attempt to pave the way for such research, or in other words as merely a foundation on which a more substantial edifice may be gradually built by future workers.

As the title indicates, this work deals with the trees of India mainly from a silvicultural point of view. Exception may therefore be taken to the inclusion of botanical descriptions and drawings of the seedlings of many of the species. The importance of the seedling, as marking the most critical stage in the life of the tree, will be emphasized later. Meanwhile it may be mentioned that one of the chief difficulties experienced at present in studying the reproduction of forest trees is the fact that the seedlings of many of the species are difficult to recognize in all their stages. In course of time a more or less complete botanical study of the seedlings will no doubt be made, and a critical systematic account of them will then be possible. It is doubtful, however, if this will be accomplished for a long time to come; meanwhile it is considered advisable to include in the present work drawings and descriptions of those seedlings which have already been studied, since these comprise the greater proportion of the more important forest tree seedlings the identification of which is essential if any marked progress is to be made in the study of the trees in question. The descriptions have been made either from seedlings raised artificially or from natural seedlings collected in the forest; with very few exceptions they have been made from fresh, and **not from dried** specimens. The drawings have been executed by the artists of the Forest Research Institute at Dehra Dun, under my supervision. It should be mentioned that seedlings exhibit great differences, due to the conditions under which they are grown, in the dimensions of their leaves, stems, and other parts, and it is therefore difficult to give dimensions with any degree of accuracy; the dimensions given in the descriptions are taken from actual specimens examined, but they should not be regarded as defining absolutely the sizes of leaves and other parts of seedlings grown under all conditions.

Although this work deals primarily with forest trees of the Indo-Burmese region, a certain number of exotics have also been included, more particularly those, such as *Eucalyptus* spp., which are already grown to some extent in plantations or are otherwise of some interest. Indian species regarding which nothing is known silviculturally have as a rule been omitted altogether. The arrangement of genera and species according to botanical natural orders, which is adopted in the present work, is to a great extent logical from a silvicultural point of view, for botanically allied species often exhibit silvicultural affinities in a marked degree.

CONDUCT OF SILVICULTURAL RESEARCH AT DEHRA DUN AND ELSEWHERE. A preliminary study of the factors affecting the reproduction of trees and the growth and survival of seedlings was carried out by means of experimental plots at Dehra Dun, where over 2,000 such plots were under observation at one time or another; some of the Himalayan species were subsequently studied in experimental plots at Simla at an altitude of 7,000 ft. Control plots were also maintained and kept under observation in various forest tracts with the view of supplementing the preliminary plots at Dehra Dun. The preliminary experimental plots were designed for the most part with the object of ascertaining for each species the factors which affect germination, particularly under natural conditions, and those which influence the development and survival of the seedling; such factors include temperature, moisture, light, soil-texture, soil-covering, &c., as well as animals, birds, and insects. In connexion with these preliminary experimental plots it must be emphasized that although useful, indeed essential, for the close study of the factors bearing on reproduction and other questions, they cannot be regarded as the sole basis for general conclusions. The latter can be formed only after further close study in the forest under the varying conditions met with in different localities: in connexion with such further study, however, the preliminary experimental plots have proved invaluable. Although Dehra Dun is no doubt a favourable centre for the preliminary study of a large number of Indian species, and although I have in some respects had exceptional opportunities for studying the habits of forest trees in many different localities, still local conditions vary to such an extent, even within comparatively narrow limits, that there is always scope for further study on the spot; this will, it is hoped, dispel any idea that finality is claimed for the results recorded in this work, and that there is not abundant scope for further local study even in the case of those trees which have been somewhat fully dealt with.

It may be of interest to describe briefly the forest vegetation and climatic conditions at or in the neighbourhood of Dehra Dun, where most of the preliminary experimental plots were established. Situated in a valley between the outer ranges of the Himalaya and the outlying Siwalik hills, at an elevation of about 2,200 ft., with a comparatively heavy rainfall, Dehra Dun forms in many respects an admirable centre for the conduct of experimental work dealing with species differing widely in geographical distribution and climatic range. The surrounding forests are composed largely of sal (*Sharea robusta*), with many of the miscellaneous species found in the Indian Peninsula, north-eastern India, or Burma, among which are the following :

Anonaceae, *Miliusa velutina* ; Malvaceae. *Kydia calycina*, *Bombax malabaricum* ; Sterculiaceae, *Sterculia villosa*, *Pterospermum acerifolium* ; Rutaceae, *Aegle Marmelos* ; Burseraceae, *Garuga pinnata* ; Meliaceae, *Cedrela Toona* ; Rhamnaceae, *Zizyphus Jujuba*, *Z. Xylopyrus* ; Sapindaceae, *Schleichera trijuga* ; Anacardiaceae, *Buchanania latifolia*, *Semecarpus Anacardium*, *Mangifera indica* (probably escaped from cultivation), *Odina Wodier*, *Spondias mangifera* ; Leguminosae, *Dalbergia Sissoo*, *Ougeinia dalbergioides*, *Erythrina suberosa*, *Butea frondosa*, *Cassia Fistula*, *Bauhinia racemosa*, *B. malabarica*, *B. purpurea*, *B. variegata*, *Acacia Catechu*, *Albizzia odoratissima*, *A. procera*, *A. stipulata* ; Rhizophoraceae, *Carallia lucida* ; Combretaceae, *Terminalia belerica*, *T. Chebula*, *T. tomentosa*, *Anogeissus latifolia* ; Myrtaceae. *Eugenia Jambolana*, *E. operculata*, *Careya arborea* ; Lythraceae, *Lagerstroemia parviflora* ; Samydaceae, *Casearia glomerata*, *C. tomentosa* ; Rubiaceae, *Adina cordifolia*, *Stephegyne diversifolia*, *Hymenodictyon excelsum* ; Ebenaceae, *Diospyros Embryopteris* ; Apocynaceae, *Carissa spinarum*, *Alstonia scholaris*, *Holarrhena antidysenterica*, *Wrightia tomentosa* ; Boraginaceae, *Cordia Myxa*, *Ehretia laevis* ; Bignoniaceae, *Oroxylum indicum*, *Stereospermum suaveolens* ; Verbenaceae, *Gmelina arborea* ; Lauraceae, *Litsaea sebifera*, *L. polyantha* ; Euphorbiaceae, *Bridelia retusa*, *Phyllanthus Emblica*, *Bischoffia javanica*, *Trewia nudiflora*, *Mallotus philippinensis* ; Ulmaceae, *Holoptelea integrifolia* ; Moraceae, *Ficus bengalensis*, *F. Rumphii*, *F. Cunia*, *F. glomerata*, and other species ; Salicaceae, *Salix tetrasperma*.

The typical sub-Himalayan species *Dalbergia Sissoo* is abundant in riverain tracts. Certain species usually characteristic of tropical forest, for instance *Carallia lucida* and *Calamus tenuis*, occur naturally in swampy localities in the neighbourhood of Dehra Dun. On the other hand, certain Himalayan species which ascend to 6,000 ft. or more also occur naturally in the Dehra Dun valley, for instance *Pyrus Pashia*, *Ficus palmata*, and in swampy localities *Acer oblongum*, *Quercus incana*, and *Celtis australis*. Certain trees of the temperate Himalaya have been planted at Dehra Dun ; *Cupressus torulosa* and *Quercus incana* grow well, the latter regenerating naturally with freedom, while the deodar and blue pine grow fairly well for a time, though they do not attain large dimensions and fail to ripen their seed. *Pinus longifolia* flourishes, growing rapidly and regenerating naturally where conditions are favourable. At the same time many trees of the warmer regions thrive fairly well when introduced, for instance *Dillenia indica*, *Lagerstroemia Flos-Reginae*, *Albizzia lucida*, *Tectona grandis*, *Sterculia alata*, *Mimusops Elengi*, *Amoora Rohituka*, *Saraca indica*, *Michelia Champaca*, *Dalbergia latifolia*, and others, while among Burmese trees *Xylia dolabriformis*, *Dalbergia cultrata*, *D. Oliveri*, and *Lager-*

stroemia tomentosa have recently been introduced and show some promise. The more tender tropical trees, however, do not survive the winter cold at Dehra Dun. Meteorological statistics show that the normal rainfall at Dehra Dun observatory, the mean of 33 years, is 85·22 in., distributed as follows :[1]

January	2·27	July	27·00
February	2·33	August	30·55
March	0·98	September	9·43
April	0·70	October	0·89
May	1·48	November	0·30
June	8·42	December	0·87

This shows the monsoon climate typical of India as a whole, the great bulk of the rain falling during the period of the south-west monsoon. The following shade temperatures recorded at Dehra Dun prior to 1903 may also be quoted :[2]

Absolute maximum	111·0° F.
Absolute minimum	33·9° F.
Highest mean monthly maximum for year	95·0° F.
Lowest mean monthly minimum for year	44·8° F.
Highest mean daily maximum for year	97·0° F.
Lowest mean daily minimum for year	44·4° F.

Such is the locality in which most of the preliminary investigations into conditions affecting the reproduction and early life-history of the trees dealt with in this work were carried out. The species of the temperate Himalaya, however, form an important exception ; these were studied in detail in their own habitat. The more tender tropical species, again, have for the most part not yet been studied in any detail.

CLIMATE OF INDIA. An appreciation of the climatic conditions prevailing in India is of such importance in connexion with the study of the various forest types met with and of their component species, that a brief sketch of these conditions will not be out of place before we proceed to a consideration of the chief forest types.

The climatic conditions of India probably show more variation than those of any other tract of similar area in the world. The normal rainfall varies from less than 3 inches a year in upper Sind to 460 inches at Cherrapunji in the Assam hills and over 300 inches in exposed positions at the top of the Western Ghats and in the hills of Arakan and Tenasserim. Actually a rainfall of 905 inches was recorded at Cherrapunji in the year 1861, while in upper Sind years have been recorded during which no rain fell.

The rainfall of India is governed mainly by the monsoons, of which there are two, the south-west or wet monsoon and the north-east or dry monsoon : of the two the former is by far the more important, bringing as it does about 90 per cent. of the rainfall. Owing to the influence of the monsoon the year may, throughout the greater part of India, be divided into a wet season from May–June to September–October and a dry season throughout the rest of the year. The south-west monsoon, starting from the south and bringing moisture-laden air currents from the Indian Ocean and Arabian Sea, is diverted owing to the rotation of the earth and strikes the coasts of India and Burma from a south-westerly direction. The monsoon proper lasts from June to September, during which period almost general rain falls throughout the greater part of India. The period from October to December, during which the humid currents pass out of the Indian region to the equatorial belt, is known as the retreating monsoon period. November and December are characterized by fine weather, clear skies, a large diurnal range of temperature, and low humidity, but during these two months cyclonic storms sometimes give rainfall in the Deccan and southern Madras coast districts, particularly along the Coromandel coast, and also produce occasional heavy rain in the Nilgiris. By the beginning of January the north-east monsoon is fully established over the Indian region. The dry winds of this monsoon blow from a general north-easterly direction; they bring regular rainfall only when they pass over the Bay of Bengal and acquire humidity, which they deposit in the form of rain over the south-eastern portion of the Indian Peninsula. During the cold season the rainfall is greatest in the submontane districts of northern India; it decreases away from the hills and is negligible over the greater part of the Peninsula and in Lower Burma. The cold season, however, is in many localities characterized by heavy night dews, which exercise a beneficial effect on vegetation. The chief feature of the cold weather precipitations is the heavy snowfall which takes place in the higher ranges of the Himalaya, increasing in amount with elevation. The second half of the dry season includes the months of March, April, and May, which are characterized by high temperatures and an absence of rain, except for occasional storms of a local nature, sometimes accompanied by hail: in Burma the second half of May is characterized by frequent and often heavy showers of rain preceding the monsoon proper.

---

[1] Gilbert T. Walker, Monthly and Annual Rainfall Normals, Mem. Ind. Met. Dept. vol. xxii, pt. i, 1913.

[2] Sir John Eliot, Normal Monthly and Annual Means of Temperature, &c., *ibid.* vol. xvii, 1904.

The rainfall map gives a clear picture of the effects of the monsoon currents. The regions of heaviest rainfall coincide with the occurrence of hill ranges which intercept the moisture-laden currents. The dry Deccan districts, over which the currents pass after depositing the greater part of their moisture on the Western Ghats, have for the most part a rainfall of less than 30 inches. A similar dry region, where the rainfall is less than 40 inches and in places is not much over 20 inches, is the dry zone occupying the central and southern part of Upper Burma: here the forest vegetation bears a similarity to that of the dry Peninsular region.

The rainfall is closely connected with atmospheric humidity. In some of the coastal and hill regions the rainy season is characterized by excessive humidity, amounting almost to supersaturation, while in the drier regions during the hottest part of the dry season the atmospheric dryness is so excessive that the usual methods employed in calculating the humidity have failed.

So far as forest vegetation is concerned the dry hot-weather months are in some respects critical ones, in that they mark the season of forest fires, which exercise a considerable influence on the constitution and type of the crop by encouraging fire-resisting species at the expense of the more sensitive species. Trying though the hot season is, the vegetation nevertheless adapts itself to this annual period of heat and drought, the great majority of the deciduous trees shedding their leaves early in the season and remaining leafless during a part or the whole of it. Of greater importance is the rainy season, for it is the season which governs the rainfall, and therefore exercises a predominating influence on the broad classification of climatic forest formations in India. Damage to forests by abnormal drought, which in certain years takes place on an extensive scale, is due not to conditions prevailing in the regular hot weather months, but to failure of the monsoon rains.

Temperature is another important factor which, in conjunction with rainfall and atmospheric humidity, determines the character of the forest vegetation. Temperature readings by the Meteorological Department of India are taken under conditions as far as possible similar: the thermometers are placed with their bulbs 4 ft. above ground in open sheds where free circulation of air is permitted, the sheds being covered with a thick roof. The temperature figures in this work, which are quoted from the Indian Meteorological Memoirs, are the absolute maximum and minimum shade temperatures measured in this way prior to 1903. These absolute figures give a clearer indication of the extremes which the various species have to encounter in their natural habitat than figures showing average monthly or annual means of maximum and minimum temperatures would give. It should be noted, however, that these absolute temperatures are measured under cover, and do not represent either the actual maximum to which the plants are exposed during the day, taking into account the direct heat of the sun and the heat reflected from the ground, or the actual minimum to which they are exposed at night when loss of heat by radiation is taken into consideration. Thus the absolute minimum temperature quoted is frequently well above freezing-point in the case of species which are known to occur in localities subject to annual frost. For comparative purposes, however, the absolute maximum and minimum shade temperatures as recorded by the Meteorological Department are of much greater value than temperature figures recorded under different conditions of insolation, radiation, and other factors.

The diurnal and annual ranges of temperature are of some importance in regulating the distribution of species. The diurnal range is affected chiefly by the presence of clouds and by the humidity. It is much greater in the dry than in the wet season, being usually greatest in November; it is least on the coast and increases on proceeding inland, reaching a maximum in the dry regions of the Punjab and upper Sind. The annual range is likewise smallest in the coast districts and greatest in regions far from the sea and in the driest districts.

As might be expected in a country possessing the loftiest mountain range in the world, the effect of altitude on the temperature, and consequently on the vegetation, is probably better illustrated in India than in almost any other portion of the globe. Thus the Himalayan range exhibits climatic regions ranging from tropical through sub-tropical, warm and cool temperate, to alpine and arctic, and the changes in the forest flora are marked by well-defined zones of altitude. The other mountain regions of India exhibit these changes on a somewhat more restricted scale.

BRIEF SKETCH OF THE FOREST VEGETATION OF INDIA. From a silvicultural or oecological point of view a mere description of the various types of forest met with in any region is in itself of small interest compared with a study of the factors which on the one hand affect their general distribution and on the other determine their origin in and their occupancy of any given locality. Consideration of these complex factors, however, will be much facilitated if we commence with a brief sketch of the forest vegetation of India, largely from a floristic point of view. In such a sketch it will be impossible to do more than give a rough idea of the main types of forest met with, and this can be done most conveniently according to geographical regions determined as far as possible by the character of the forest flora. For our purpose it will be convenient to recognize twelve different regions, namely, (1) the western Himalayan region, (2) the eastern Himalayan region, (3) the trans-Indus region, (4) the north-western dry region, (5) the Gangetic plain, (6) the west coast region, (7) the central Indian region, (8) the Deccan and Carnatic, (9) Assam, (10) Chittagong and Arakan, (11) Burma, (12) the Andamans.

1. *The western Himalayan region.* This region comprises the sub-Himalayan tract and the Himalayan range from Kumaun to Chitral. It is characterized by a rainfall varying for the most part from 40 to 80 in., though in some parts of the submontane tracts it reaches 100 in. or more, while in the inner valleys and towards the north-west frontier the climate is dry or even arid. This region is divisible into three zones of altitude: (*a*) the submontane zone and lower hills, up to about 5,000 ft.; (*b*) the temperate zone, from about 5,000 to 11,000–12,000 ft.; (*c*) the alpine zone, from 11,000–12,000 ft. up to about 15,000 ft.

(*a*) The submontane tract contains an almost continuous belt of sal forest running, with occasional breaks, throughout the eastern portion of the tract as far west as the Jumna, and to a very small extent beyond; details of this sal belt, which extends into the sub-Himalayan valleys and ascends the outer hills in places, will be found under *Shorea robusta.* The sal belt is broken at intervals by savannah lands with scattered trees, chiefly *Butea frondosa* and *Bombax malabaricum*, or by different types of forest, for instance (i) riverain forests of *Acacia Catechu* and *Dalbergia Sissoo* (described under these species): (ii) swamp forests of *Eugenia Jambolana, Diospyros Embryopteris, Albizzia procera, Ficus glomerata, Bischoffia javanica, Pterospermum acerifolium, Cedrela Toona, Celtis australis, Trewia nudiflora, Putranjiva Roxburghii, Salix tetrasperma*, and other trees, with the cane *Calamus tenuis*; (iii) dry thorn forests of *Zizyphus Jujuba, Z. Xylopyrus, Acacia Catechu*, and others; (iv) mixed deciduous forests containing *Terminalia* spp., *Bombax malabaricum, Lagerstroemia parviflora, Anogeissus latifolia, Stereospermum suaveolens, Phyllanthus Emblica, Adina cordifolia, Ougeinia dalbergioides, Odina Wodier, Hymenodictyon excelsum, Holoptelea integrifolia, Cassia Fistula*, and many other species. These mixed forests ascend the outer hills to between 3,000 and 4,000 ft., the bamboo *Dendrocalamus strictus* occurring in great abundance in places on the lower slopes. As the elevation increases new species such as *Bauhinia retusa, Sapium insigne, Engelhardtia spicata, Boehmeria rugulosa, Pistacia integerrima*, and *Euphorbia Royleana* make their appearance, while some of the trees of the lower elevations are no longer found: finally *Pinus longifolia* appears, at first scattered among other species but soon forming extensive pure forests towards the upper limit of this zone. In the western part of this region, in the Jhelum and Rawalpindi districts and in the North West Frontier Province, the forest becomes drier in character, the prevailing species in the submontane tracts and outer hills being *Acacia modesta*, *Olea cuspidata*, *Carissa spinarum*, *Dodonaea viscosa*, and other xerophytic species.

(*b*) The temperate zone, which begins at about 5,000 ft. and ascends to 11,000–12,000 ft., contains extensive forests of conifers and broad-leaved trees. Of the former *Pinus longifolia* enters the zone, but is confined to the lower elevations and soon gives place to deodar (*Cedrus Deodara*) and blue pine (*Pinus excelsa*), while higher up spruce (*Picea Morinda*) and silver fir (*Abies Pindrow*) make their appearance and form forests of large extent, mainly between 8,000 and 11,000 ft.; of other conifers the yew (*Taxus baccata*) is common in some localities, while the cypress (*Cupressus torulosa*) is found locally, and the edible pine (*Pinus Gerardiana*) occurs in the inner dry valleys. The broad-leaved trees comprise oaks, of which *Quercus incana*, *Q. dilatata*, and *Q. semecarpifolia* are the chief, with *Q. Ilex* in the drier valleys, maples, horse-chestnut (*Aesculus indica*), poplar (*Populus ciliata*), elm (*Ulmus Wallichiana* being the chief), alder (*Alnus nepalensis* and *A. nitida*, the latter descending below the zone), birch (*Betula alnoides*), *Cornus*, *Prunus Padus*, *Rhododendron arboreum*, and other trees.

(*c*) The alpine zone extends from 11,000–12,000 ft. up to about 15,000 ft. or sometimes higher. The characteristic trees are the high-level silver fir, the silver birch (*Betula utilis*), and junipers. Rhododendrons are far less numerous than in the eastern Himalaya, and are represented by three shrubby species.

2. *The eastern Himalayan region.* This region, extending from Sikkim eastwards, embraces the most humid portion of the Himalayan range. Nepal, owing to want of knowledge of its forest flora, constitutes a gap between the western and eastern regions as here defined. The eastern region may be divided into three zones of altitude: (*a*) the tropical zone, up to about 5,000 ft.; (*b*) the temperate zone, from 5,000 to 12,000 ft.; and (*c*) the alpine zone, from 12,000 to 16,000 ft.

(*a*) The tropical zone begins with a forest belt stretching some distance out into the plains and consisting of several different types of forest, the chief of which are (i) sal forests, described in some detail under *Shorea robusta*, and including the sal savannah tracts, in which the dominant grass is *Saccharum Narenga*; (ii) riverain forests of *Dalbergia Sissoo* and *Acacia Catechu*; (iii) mixed deciduous forests of *Terminalia* spp., *Lagerstroemia parviflora*, *Sterculia villosa*, *Bombax malabaricum*, *Duabanga sonneratioides*, *Anthocephalus Cadamba*, *Schima Wallichii*, *Gmelina arborea*, *Cedrela Toona*, *Albizzia procera*, *Premna*, *Bauhinia*, *Stereospermum*, &c.; (iv) moist savannah forests, consisting of stretches of tall savannah grasses, of which *Saccharum procerum* is among the commonest, with scattered trees, among the chief of which are *Albizzia procera*, *Bombax malabaricum*, and *Bischoffia javanica*; (v) evergreen forests with a large number of species, among which are *Michelia Champaca*, *Schima Wallichii*, *Artocarpus Chaplasha*, *Dillenia indica*, *Talauma Hodgsoni*, *Aesculus punduana*, *Amoora*, *Eugenia*, *Echinocarpus*, *Eurya*, *Garcinia*, *Elaeocarpus*, *Cinnamomum Cecidodaphne*, *Canarium sikkimense*, and *Ficus elastica*, the last

named now rare, there are numerous canes, climbers and evergreen shrubs forming a dense impenetrable undergrowth.

In the outer hills sal, where present, occurs chiefly on the ridges, the intervening depressions and valleys being occupied by moist mixed forest in which the bamboo *Dendrocalamus Hamiltonii* is often abundant. In the upper part of this zone two characteristic trees, *Betula cylindrostachys* and *Alnus nepalensis*, make their appearance.

(*b*) The temperate zone, from 5,000 to 12,000 ft., may be divided into two belts: (i) the lower belt below 9,000 ft., containing a large number of different broad-leaved species, including *Quercus lamellosa*, *Q. lineata*, *Q. pachyphylla*, and other oaks, *Castanopsis*, *Michelia excelsa* and other Magnoliaceae, *Bucklandia populnea*, *Cedrela*, many laurels and maples, alder, birch, *Pyrus*, *Symplocos*, *Echinocarpus*, *Elaeocarpus*, *Meliosma*, and *Eurya*; (ii) the upper hill forests, above 9,000 ft., consisting for the most part of conifers, *Abies Webbiana*, *Picea spinulosa*, *Larix Griffithii*, *Tsuga Brunoniana*, and two junipers, as well as numerous rhododendrons, dwarf willow, and other shrubs; the bamboo *Arundinaria racemosa* forms a dense growth in places.

(*c*) The alpine zone, above 12,000 ft., is rich in rhododendrons, which ascend to 16,000 ft.; the junipers of the upper temperate zone also extend high into this zone.

3. *The trans-Indus region.* This region comprises the trans-Indus hills of the North West Frontier Province and Baluchistan. In the northern part of this region, extending southward as far as the Kurram valley, the forests approximate in type to those of the western portion of the western Himalayan region. Farther south, in Baluchistan, where the rainfall does not exceed 12 in. and is often considerably less, most of the Himalayan conifers disappear, and the forests become much drier and poorer in type; *Pinus excelsa* is very local in the north of Baluchistan, being confined to places where moisture is held up in the soil, while *P. Gerardiana* forms forests of some extent, as in Zhob and on the Takht-i-Suliman. The chief conifer of Baluchistan is *Juniperus macropoda*, which forms somewhat open forests. Among other trees or shrubs of this region may be mentioned *Pistacia mutica*, *P. Khinjak*, *Fraxinus xanthoxyloides*, *Olea cuspidata*, *Acacia modesta*, *Tamarix* spp., *Crataegus Oxyacantha*, and *Tecoma undulata*. In some parts of the trans-Indus region the small gregarious palm *Nannorhops Ritchieana* occurs in tracts of considerable extent.

4. *The north-western dry region.* This region comprises the plains of the Punjab and Sind, Rajputana, Cutch, and the northern part of Guzerat. The rainfall is less than 30 in., and in most parts of the region is under 20 in., while in the driest parts of Sind less than 5 inches of rain fall in the year. In the extreme north of this region, on the hills and elevated plateaux between the Jhelum and the Indus, the dominant species are *Acacia modesta* and *Olea cuspidata*, with most of the shrubs characteristic of the sub-Himalayan tract to the north. On proceeding south vegetation diminishes towards the desert regions of the southern Punjab, Sind, and Rajputana, and almost disappears in the driest parts. Tree vegetation here exists mainly along the rivers, where the land is subject to periodical inundation. These riverain forests are well exemplified along the Indus in Sind, where there are extensive areas

covered with *Acacia arabica*, *Prosopis spicigera*, *Populus* ***euphratica***, and *Tamarix*; a description of these riverain forests will be found under ***Acacia*** *arabica*. The natural forests of the dry plains of the Punjab, Sind, and Rajputana, where they have not been destroyed for cultivation, consist of ***Prosopis*** *spicigera*, *Salvadora oleoides*, and *Capparis aphylla*, forming a very open growth. These species rapidly disappear with the extension of irrigation, their place being taken by such trees as *Acacia arabica*, *Albizzia Lebbek*, ***Dalbergia Sissoo***, and others which have escaped from cultivation. To the south-east of this region lie the Aravalli hills and their outliers, commencing with a few isolated rocky hills in the south-east of the Punjab. Here the desert flora of the dry plains gives place to dry and somewhat open types of forest consisting in places almost entirely of *Anogeissus pendula*. Other characteristic species of these hills and the adjacent tracts are ***Boswellia serrata***, ***Sterculia urens***, ***Grewia*** *salvifolia*, *G. pilosa*, *Balanites Roxburghii*, *Acacia Senegal*, ***A. leucophloea***, *A. Jacquemonti*, *A. Catechu*, *Dichrostachys cinerea*, ***Balsamodendron Mukul***, *Zizyphus nummularia*, and *Euphorbia Nivulia*. These forests are for the most part typical thorn forests.

5. *The Gangetic plain*. The great bulk of the Gangetic plain is a cultivated tract: the forests, where they exist, are of widely different types. The extreme south-west of this region borders on the Aravalli hills, and the forest vegetation is of the type just described. The ravine country south of the Jumna contains open thorn forest of ***Acacia arabica***, ***A. leucophloea***, and other species. The two most important forest tracts of this region are the sal forests of Oudh and the littoral and tidal forests of the Sundarbans. The Oudh sal forests, as they exist now, are probably mere remnants of the great sub-Himalayan sal belt, which at one time covered a much larger area than it does at present and stretched for some distance into the plains; strictly speaking they can hardly be differentiated from the sub-Himalayan *tárai* forests. These forests are described under ***Shorea robusta***. The Sundarbans form an extensive forest tract occupying a flat plain of recent alluvial origin, and still in process of formation, in the southern portion of the Gangetic delta bordering on the Bay of Bengal. The chief species in this tract are ***Heritiera*** *Fomes*, *Excaecaria Agallocha*, *Sonneratia apetala*, *S. acida*, ***Carapa moluccensis***, *C. obovata*, *Amoora cucullata*, *Aegiceras majus*, *Cynometra ramiflora*, *Avicennia officinalis* and the mangroves *Ceriops Candolleana*, *C. Roxburghiana*, *Kandelia Rheedii*, *Rhizophora mucronata*, and *Bruguiera gymnorhiza*. Further particulars regarding these forests will be found under ***Heritiera Fomes*** and Rhizophoraceae.

6. *The west coast region*. This region, which is one of heavy rainfall, comprises the excessively humid belt of mountainous country running parallel to the west coast of the Indian Peninsula from the south of Guzerat to Cape Comorin, together with the low country between the mountains and the coast. Owing to a gap separating the mountains of Travancore from those to the north of them the flora of this region is carried some distance across the Peninsula at this point. Broadly speaking the forests of this region may be divided into three main types: (*a*) tropical evergreen or rain forests, (*b*) mixed deciduous or monsoon forests, and (*c*) subtropical or temperate evergreen forests of the Nilgiris and other mountains of southern India.

(*a*) The tropical evergreen or rain forests are characterized by the great luxuriance of their vegetation, which consists of several tiers, the highest containing lofty trees, often with buttressed bases, reaching a height of 150 ft. or more, and the lowest consisting of a dense shrubby evergreen undergrowth. The intermediate tiers consist mainly of evergreen trees crowded together and struggling for light. There is a luxuriant growth of climbers, while the trees are covered with numerous epiphytes. The rain forests of the west coast region are found mainly from North Kanara southwards: much of the forest, however, has been either destroyed by shifting cultivation or cut up by spice and betel-palm gardens, or in the south by rubber plantations. Among the trees of the evergreen forests are *Dipterocarpus indicus*, *Hopea parviflora*, *H. Wightiana*, *Calophyllum tomentosum*, *Cullenia excelsa*, *Dichopsis elliptica*, *Dysoxylum malabaricum*, *Cedrela Toona*, *Vateria indica*, *Canarium strictum*, *Tetrameles nudiflora*, *Mesua ferrea*, *Mangifera indica*, *Sterculia alata*, *Artocarpus hirsuta*, *A. integrifolia*, *A. Lakoocha*, *Acrocarpus fraxinifolius*, *Hydnocarpus Wightiana*, and many Myristicaceae and Lauraceae.

(*b*) The mixed deciduous or monsoon forests are composed mainly of deciduous trees, which are more or less leafless for a considerable portion of the dry hot season from December to May or June. These forests are rich in woody climbers, but are not so dense as the evergreen forests, nor do they contain such lofty trees. They occur in different parts of this region, but are most plentifully developed in the north. This type of forest, which is essentially a mixed one, is of special importance in that it contains several species of great economic value as timber trees. Among the principal species are *Tectona grandis*, *Dalbergia latifolia*, *Terminalia tomentosa*, *T. paniculata*, *T. belerica*, *Lagerstroemia lanceolata*, *L. parviflora*, *Pterocarpus Marsupium*, *Xylia xylocarpa*, *Adina cordifolia*, *Stephegyne parvifolia*, *Grewia tiliaefolia*, and others: the chief bamboos are *Bambusa arundinacea*, *Dendrocalamus strictus*, and *Oxytenanthera monostigma*, the last named mainly on the upper slopes of the hills. This type of forest merges on the one hand into the evergreen type and on the other into the drier types of mixed deciduous forest in the Deccan region.

(*c*) The subtropical or temperate evergreen forests, known locally as *sholas*, commence at about 5,000 ft., and are a characteristic feature of the landscape on the Nilgiri, Anaimalai, Palni, and other hill ranges of southern India. At the lower elevations they merge into tropical evergreen, but higher up, at the more temperate elevations, they are composed mainly of evergreen trees of comparatively small size with rounded crowns, and have a rich undergrowth in which species of *Strobilanthes* are well represented. Among the more characteristic trees are *Michelia nilagirica*, *Ternstroemia japonica*, *Eurya japonica*, *Gordonia obtusa*, with species of *Eugenia*, *Ilex*, *Meliosma*, *Euonymus*, *Symplocos*, *Glochidion*, and various Lauraceae. At the lower elevations *Mesua ferrea* is found, and *Hydnocarpus alpina* is common. The two commonest bamboos of these hills are *Arundinaria Wightiana* and *Oxytenanthera Thwaitesii*.

Apart from the three main types just described there are other forest types of a more local character. Among these may be mentioned (i) mangrove forests along tidal creeks; (ii) littoral forests of *Calophyllum Inophyllum*, *Anacardium occidentale*, *Salvadora persica*, *Erythrina indica*, ***Ficus tomentosa***, and *Pongamia glabra*; (iii) dwarf forests of a montane type, but containing species characteristic of low elevations, such as ***Eugenia Jambolana*** and others, at 4,500 ft. on the laterite of the Mahableshwar plateau where the rainfall is over 300 in.; (iv) tree or bush forests of the Nilgiri and other south Indian hills in drier localities than those occupied by the *sholas*, with such species as *Rhododendron arboreum*, *Vaccinium Leschenaultii*, and ***Gaultheria fragrantissima***.

Apart from the forest tracts, the upper parts of the Nilgiri and other south Indian hills are characterized by the presence of expanses of open undulating grassland. Exotic trees have been introduced very successfully on these hills, particularly eucalypts and Australian acacias (see under ***Eucalyptus*** and ***Acacia***).

7. *The central Indian region.* This region comprises the country between the Gangetic plain on the north and the Godavari river on the south, and includes the whole of the Central Provinces, Chota Nagpur, Orissa and the Circars, Khandesh, the southern part of Guzerat, and the greater part of the Central India States. Within this region fall the two great hill ranges of central India, the Vindhya and Satpura hills. The rainfall varies from 25 to 65 inches, except that the latter is exceeded on the plateaux of Pachmarhi and Chikalda. The great bulk of the forests in this region consist either of (*a*) mixed deciduous forests of a type which is virtually a dry form of monsoon forest, or (*b*) sal forests, or (*c*) thorn forests. The distribution of these types is determined partly by climatic conditions, but also to a considerable extent by soil conditions.

(*a*) The mixed deciduous forests vary in composition, but the prevailing trees are *Tectona grandis*, *Terminalia tomentosa*, *T. belerica*, *T. Chebula*, *Anogeissus latifolia*, *Lagerstroemia parviflora*, *Pterocarpus Marsupium*, *Dalbergia latifolia*, *Ougeinia dalbergioides*, *Cassia Fistula*, *Acacia Catechu*, *Butea frondosa*, *Adina cordifolia*, *Stephegyne diversifolia*, *Bridelia retusa*, *Phyllanthus Emblica*, *Cleistanthus collinus*, *Diospyros Melanoxylon*, *Bassia latifolia*, *Soymida febrifuga*, *Schrebera swietenioides*, *Chloroxylon Swietenia*, *Odina Wodier*, *Buchanania latifolia*, *Schleichera trijuga*, and various other trees; the prevailing bamboo is *Dendrocalamus strictus*. On ridges and in other dry situations the forest is often of a special kind in which *Boswellia serrata*, *Sterculia urens*, and *Cochlospermum Gossypium* are the chief species. In the moister types of forest to the south-east of this region *Xylia xylocarpa* becomes common. As a general rule the mixed deciduous forests of this region do not contain trees of large dimensions, and compare unfavourably in this respect with the mixed deciduous forests of the west coast or of Burma. In the more favourable localities, as in moist ravines and on deep fertile soil, forest of very fair quality is produced, but over a considerable portion of the region the forest is of a dry type often merging into thorn forest. Teak trees of small size are very plentiful in places. There are various special types of mixed deciduous forest in this region, one of the most notable being the *anjan* (***Hardwickia binata***) type found either on trap or on sandy and gravelly soil overlying granite, schist, quartzite, conglomerate, or sandstone (see under ***Hardwickia binata***). In parts of Central India *Anogeissus pendula* grows gregariously, forming a special type of forest. Some of the drier and more open types of mixed deciduous forest, in which rather stunted trees are scattered over grassy expanses, may be classed as dry savannah forests.

(*b*) The sal forests extend through the eastern part of the Central Provinces, the greater part of Chota Nagpur and Orissa, and the north-eastern portion of the Madras Presidency. Their distribution is determined largely by the hygroscopicity of the soil and subsoil, for which reason they avoid trap areas, which are too dry for their existence. These forests are described in some detail under *Shorea robusta*. Associated with the sál forests are occasional tracts of savannah land.

(*c*) Thorn forests occur in all the drier parts of this region, chiefly on the more level ground on the extensive plateaux of Central India. They are of an open character, vary in composition, and consist to a large extent, though by no means exclusively, of thorny species, many of which belong to the Leguminosae; among characteristic species of the thorn forests of this region may be mentioned *Acacia arabica*, *A. leucophloea*, *A. Catechu*, *Dichrostachys cinerea*, *Balanites Roxburghii*, *Butea frondosa*, *Phyllanthus Emblica*, *Zizyphus Xylopyrus*, *Z. nummularia*, and *Z. Oenoplia*. *Prosopis spicigera* occurs only in the driest parts of this region. Thorn forest is specially characteristic of trap areas and black cotton soil, though by no means confined to such ground.

8. *The Deccan and Carnatic.* This region includes the whole of peninsular India south of the Godavari river with the exception of that portion which falls into the humid west coast region. It is divisible into two main sub-regions: (*a*) the elevated and often hilly plateau of the Peninsula, which may be termed the Deccan sub-region, and (*b*) the low land along the east (Coromandel) coast, which may be termed the Carnatic sub-region. Throughout the greater part of the former the rainfall is less than 40 in., this amount being exceeded only at certain elevated points which intercept the monsoon currents (e. g. Yercaud 63 in.). The latter sub-region receives the full benefit of the north-east monsoon, and has a rainfall which throughout the greater part of its extent varies from 40 to nearly 60 in.

(*a*) The Deccan sub-region is characterized by dry open types of forest, varying from mixed deciduous forest similar to the drier types found in the central Indian region, to open thorn forest similar to that of the driest parts of that region, with *Prosopis spicigera* more plentiful towards the south. Other typical thorn-forest species, which do not occur in other Indian regions, are *Acacia planifrons* and *A. Latronum*, while *Albizzia amara* scarcely extends beyond this region. In these thorn forests *Cassia auriculata* is a conspicuous gregarious shrub. In the more barren rocky tracts a semi-desert flora appears, with fleshy Euphorbiaceae, *Capparis divaricata*, *C. aphylla*, and other xerophytic plants. Among many special types of forest in this sub-region the following may be mentioned: (i) *Hardwickia binata* tracts occur in various localities, mainly from Salem and North Arcot to the Godavari river, usually on gravelly sand or red sandy loam, either in gregarious patches or in mixture with *Anogeissus latifolia*, *Soymida febrifuga*, *Terminalia tomentosa*, and other trees. (ii) *Pterocarpus santalinus* tracts occupy a limited range mainly in the hills of Cuddapah and North Arcot, extending into Kurnool and Nellore, with an outlier in the hills of Chingleput; this tree occurs in a dry type of mixed forest on well-drained rocky ground or stony and gravelly soil, among its more typical associates being *Pterocarpus Marsupium*, *Hardwickia* ***binata***, ***Dalbergia*** *latifolia*, *Acacia leucophloea*, ***Albizzia odoratissima***, ***Chloroxylon Swietenia***, *Terminalia Chebula*, and ***Anogeissus latifolia***. (iii) The most important sandalwood (*Santalum album*) areas are found in the uplands of Mysore, Coorg, and parts of Madras, chiefly in Coimbatore, Salem, the Nilgiris, and North Arcot. The sandalwood grows in open scrub forests on well-drained stony or gravelly soil or red ferruginous loam (see under *Santalum album*). (iv) ***Shorea*** forests of this sub-region are represented by two separate species, *S.* ***Tumbuggaia*** and *S. Talura*, each with a limited distribution; the former occurs in comparatively dry situations and somewhat resembles the sal in habit, while *S.* ***Talura*** is found more in damp ravines, and extends into the west coast region. (v) A special type of thorn forest is found in the extreme south of the Peninsula in the Madura and Tinnevelly districts, where the country is sheltered from the monsoon by the Palni hills and the hills of Ceylon, and is very hot and arid: here is found an open xerophilous woodland consisting largely of ***Acacia*** *planifrons*, with its spreading umbrella-shaped crown, and thickets of the thorny *A. Latronum*.

(*b*) The Carnatic sub-region contains, besides a certain extent of forest of the Deccan type, another type which may be termed dry evergreen, in which the chief species include *Mimusops hexandra*, *M. Elengi*, *Diospyros Ebenum*, *Strychnos Nux-vomica*, *Eugenia* spp., *Pterospermum suberifolium*, *P. Heyneanum*, *Memecylon edule*, and *Chloroxylon Swietenia*. Although the trees are not of large dimensions the forests where carefully preserved are dense, but many of them through over-felling have been reduced to the condition of thorny thickets of *Randia*, *Canthium*, *Dichrostachys*, *Flacourtia*, and ***Zizyphus***. Mangrove forests occur at the mouths of the rivers, while on the sand near the sea the palm *Phoenix farinifera* and the grass *Spinifex squarrosus* form dense thickets. Successful casuarina plantations have been formed along the coast on sandy soil.

9. *Assam.* The Assam region outside the sub-Himalayan tract, which forms part of the eastern Himalayan region, comprises the Brahmaputra and Surma valleys together with the intervening hill ranges (the Garo, Khasi, and Jaintia hills) and the Naga, Manipur, and Lushai hills on the eastern and south-eastern frontiers of Assam. Over the greater part of this region the rainfall exceeds 80 in., while Cherrapunji in the Khasi hills, with a normal rainfall of 460 in., is one of the rainiest spots in the world. In part of the Nowgong district the rainfall is as low as 45 in., but this is exceptionally dry for this region. The vegetation, as might be expected, is luxuriant. The valleys, where not under tea or agricultural crops, are clothed with expanses of tall savannah grass or with dense forest often of an evergreen type. Among the more characteristic species of the valleys and lower hills are ***Mesua ferrea***, *Artocarpus Chaplasha*, *Michelia Champaca*, *Lagerstroemia Flos-Reginae*, *Amoora Wallichii*, *Vatica lanceaefolia*, ***Alstonia scholaris***, ***Cinnamomum*** *Cecidodaphne*, *Dillenia indica*, *Dysoxylum binectariferum*, ***Garcinia*** spp., *Eugenia* spp., *Canallia lucida*, ***Baccaurea sapida***, ***Aquilaria Agallocha***, ***Sterculia*** ***alata***, *Cedrela Toona*, *Gmelina arborea*, ***Morus laevigata***, ***Stereospermum chelonoides***, *Ficus elastica* and many other species of ***Ficus***, ***Terminalia citrina***, *T. myriocarpa*, and many other trees. There are various bamboos, of which

perhaps the commonest is *Dendrocalamus Hamiltonii*, and there is often a dense impenetrable undergrowth of canes, climbers, and evergreen shrubs. Among the more typical trees in riverain areas are *Albizzia procera*, *Bischoffia javanica*, *Bombax malabaricum*, *Anthocephalus Cadamba*, *Elaeocarpus assamicus*, and *Lagerstroemia Flos-Reginae*. South of the Brahmaputra sal forest occurs in the Garo hills and in the Kamrup district.

The hill forests of the Assam region approximate in type to those of the eastern Himalayan region, except that there is no alpine zone. These hill forests may be separated broadly into evergreen broad-leaved forests and pine forests. The former include species of *Magnolia*, *Manglietia*, *Michelia*, *Acer*, *Prunus*, *Pyrus*, *Pieris ovalifolia*, *Rhododendron arboreum*, *Bucklandia populnea*, *Alnus nepalensis*, *Betula alnoides*, *Carpinus viminea*, and many species of *Quercus*. The pine forests occur at elevations of 2,500 ft. and over, particularly at 4,000–4,500 ft., and are composed of the one species *Pinus Khasya*. Shifting cultivation has destroyed much of the natural forest growth on these hills. The hill-tops of the Assam region, like those of the Nilgiris, are open grasslands with trees and shrubs identical with or closely related to those of the Nilgiris. The mountains to the east are often covered with bamboos.

10. *Chittagong and Arakan.* This is another region of heavy rainfall, the lowest normal rainfall recorded being 96 in., at Chittagong, while in places on the Arakan coast the normal rainfall exceeds 200 in. Along the coast, particularly of Arakan, there are extensive mangrove swamps, while strips of *Casuarina equisetifolia* occur here and there on beaches of pure sand. The inland forests are of evergreen or moist mixed deciduous types, and resemble those of the moister parts of Burma. Among the more characteristic trees of the evergreen forests are *Mesua ferrea*, *Dipterocarpus* spp., *Vatica* spp., *Hopea odorata*, *Sterculia alata*, *Dysoxylum binectariferum*, *Chickrassia tabularis*, *Cedrela Toona*, *Acrocarpus fraxinifolius*, *Swintonia floribunda*, *Buchanania lancifolia*, *Carallia lucida*, *Eugenia* spp., *Machilus* spp., *Baccaurea sapida*, *Tetrameles nudiflora*, and *Artocarpus Chaplasha*. Palms, including canes, are numerous. In the hill tracts various species of *Quercus* and *Castanopsis* are found.

The mixed deciduous forests contain *Dillenia pentagyna*, *Miliusa velutina*, *Pterospermum semisagittatum*, *Erythrina stricta*, *Xylia dolabriformis* (Arakan), *Albizzia stipulata*, *Bombax malabaricum*, *Terminalia tomentosa*, *T. belerica*, *T. Chebula*, *Anogeissus acuminata*, *Lagerstroemia Flos-Reginae*, *Duabanga sonneratioides*, *Adina cordifolia*, *Stephegyne parvifolia*, *S. diversifolia*, *Homalium tomentosum*, *Vitex peduncularis*, *V. glabrata*, and many other species.

Of several species of bamboo by far the most important is the single-stemmed *Melocanna bambusoides*, which covers immense tracts in the hills of Chittagong and Arakan; its growth is encouraged by shifting cultivation, which destroys the tree-growth and leaves the bamboo in sole possession of the ground.

11. *Burma.* The Burmese region, which is here taken to mean the whole of Burma including the Shan States but excluding Arakan, may be divided roughly into three zones of rainfall corresponding approximately to three dominant forest types or climatic forest formations; these zones are **A.** the humid zone, **B.** the medial zone, **C.** the dry zone. **A.** The humid zone,

with a rainfall of 120 in. or more, comprises Tenasserim and Martaban with the country east of the Sittang river up to about 19° N. lat. and perhaps in part also the Salween drainage farther north; also probably the far north of Upper Burma. If Arakan were included with Burma it would fall into this zone. The forests are mainly of the tropical evergreen type, but deciduous forests also occur to some extent, particularly where the rainfall is less than 150 in. B. The medial zone, with a rainfall of 40 to 120 in., comprises the greater part of Pegu and of Upper Burma outside the dry zone on the one hand and the humid tracts of the far north on the other. The dominant type of forest is the mixed deciduous type, otherwise termed monsoon forest, though tropical evergreen forests, sometimes of considerable extent, are also met with in moist situations, and other evergreen types are met with in the hills. The deciduous forests of this zone are, economically speaking, the most important in the province, in that they are the home of the teak and many other valuable timber trees. C. The dry zone, with a rainfall of less than 40 in., comprises the dry tract occupying the centre of the southern part of Upper Burma and extending into the Thayetmyo district of Lower Burma. In the driest parts of this zone the normal rainfall is only slightly over 20 in. The dominant type of forest is open thorn scrub.

Kurz, in his *Preliminary Report on the Forest and other Vegetation of Pegu*, 1875, and in the introduction to his *Forest Flora of British Burma*, 1877, has described in some detail the forests of what is now known as Lower Burma, and most of the types recognized by him apply to the whole province as now constituted. In his *Preliminary Report* he classified the forests of British Burma, as it then was, into seven main types and a number of sub-types. In his *Forest Flora* he reclassified them into eight main types, namely, A. Evergreen forests—I littoral, II swamp, III tropical, IV hill forests; B. Deciduous forests—V open, VI dry, VII mixed, VIII dune forests.

A classification of the forests of Burma is by no means easy, for although there is little difficulty in recognizing several well-marked types these often tend to merge into each other, and the border line is not always easy to determine. The following classification may be adopted here for brief descriptive purposes: (*a*) Tidal forests, (*b*) beach and dune forests, (*c*) swamp forests, (*d*) tropical evergreen or rain forests, (*e*) dry evergreen forests, (*f*) subtropical or temperate evergreen forests, (*g*) mixed deciduous forests, (*h*) deciduous dipterocarp forests, (*j*) thorn forests. There are various types of savannah forest, but they may be included in one or other of these main classes, into which they usually merge.

(*a*) Tidal forests comprise (i) mangrove forests on low alluvial flats within tidal limits at the mouths of the rivers, which contain true mangroves of the genera *Rhizophora*, *Ceriops*, *Kandelia*, and *Bruguiera*, together with species of other genera characteristic of this formation, such as *Carapa*, *Lumnitzera*, *Sonneratia*, *Aegiceras*, and *Avicennia*, together with the gregarious palm *Nipa fruticans* (see under Rhizophoraceae); (ii) forests farther inland on ground inundated only by spring tides, containing such species as *Heritiera Fomes*, *Pongamia glabra*, *Erythrina* spp., *Excaecaria Agallocha*, *Thespesia populnea*, some of the species of the mangrove forests, and the palm *Phoenix*

paludosa; these are the forests to which the term 'tidal forest' is usually applied.

(*b*) Beach and dune forests form comparatively narrow belts and strips along the coast of Tenasserim on the calcareous sand of beaches elevated above high-tide limits and on sand-dunes formed by the action of the wind. The trees are partly evergreen and partly deciduous, and include *Casuarina equisetifolia* (on sand-dunes), *Pongamia glabra*, *Erythrina indica*, *Thespesia populnea*, *Hibiscus tiliaceus*, *Calophyllum Inophyllum*, *Odina Wodier*, *Pandanus odoratissimus*, and others.

(*c*) Swamp forests are characteristic of inland fresh-water swamps on low-lying alluvial ground usually near rivers and lakes, and are subject to inundation during the rainy season. The species, the majority of which are evergreen, include *Barringtonia acutangula*, *Xanthophyllum glaucum*, *Anogeissus acuminata*, *Mangifera* spp., *Elaeocarpus hygrophilus*, *Eugenia operculata*, *Ixora parviflora*, *I. nigricans*, *Symplocos leucantha*, *Garcinia succifolia*, and others, and there is often a dense undergrowth of *Combretum trifoliatum* and *tetragonocarpum*, *Capparis tenera*, *Derris elegans*, and other shrubs and climbers; the higher ground is sometimes covered with tracts of coarse savannah grass.

(*d*) Tropical evergreen or rain forests are developed most extensively in Tenasserim and Martaban, where the rainfall for the most part exceeds 150 in.; they occur also to a considerable extent in the humid tracts in the far north of Upper Burma, particularly north of Mogaung. Elsewhere throughout the province outside the dry zone they occur to a greater or less extent in moist localities, particularly in shady valleys where there is a perennial water-supply. These forests are similar in type to the evergreen forests of western India and of the eastern sub-Himalayan tract. They are very rich in species, and comprise several tiers of vegetation, of which the uppermost consists of lofty and often deciduous trees, many of which have plank buttresses; the lower tiers consist mainly, if not entirely, of evergreen species struggling together in great profusion, while there is often a dense undergrowth of shade-bearing palms; climbers, including several kinds of cane, are numerous, and sometimes form an impenetrable tangled mass. Where the cover is not too dense there is often a rich undergrowth of herbaceous plants or evergreen shrubs, and frequently a soil-covering of ferns, but the overhead cover is sometimes so heavy that nothing will grow in the deep shade beneath it. Several species of bamboo are found in these forests, but in Lower Burma perhaps the commonest is *Teinostachyum Helferi*, a straggling evergreen bamboo which forms impenetrable thickets in moist localities: in Upper Burma *Dendrocalamus Hamiltonii* is common. Among the lofty trees of the upper tier in these forests are *Dipterocarpus alatus*, *D. turbinatus*, *Hopea odorata*, *Parashorea stellata*, *Sterculia alata*, *Tetrameles nudiflora*, *Acrocarpus fraxinifolius*, *Pentace burmanica*, *Swintonia floribunda*, and *Antiaris toxicaria*, while among other trees characteristic of these forests are *Artocarpus Chaplasha*, *Albizzia lucida*, *Mangifera indica*, *Baccaurea sapida*, *Amoora Rohituka*, and species of *Elaeocarpus*, *Holigarna*, *Pterospermum*, *Garcinia*, *Diospyros*, *Eugenia*, *Macaranga*, *Ficus*, *Myristica*, and many Lauraceae. There is little difference in character between the evergreen forests of Tenasserim and those of the north of Upper Burma. In the latter region most of the species just mentioned occur.

with the addition of *Ficus elastica* in certain localities, notably the Hukong valley.

(*e*) Dry evergreen forests form a distinct xerophytic type which, so far as is known, is developed only to a limited extent. This type is exemplified by the vegetation which occurs on limestone rocks in parts of the Ruby Mines district, and which consists of thorny evergreen species and euphorbias.

(*f*) The subtropical and temperate evergreen forests of the hill regions of Burma, which begin at about 3,000 to 3,500 ft., closely resemble those of Assam in the character of their forest vegetation, which is essentially evergreen. They are roughly divisible into moist and dry broad-leaved forests and pine forests. The moist evergreen forests, which occur mainly from 3,000 to 6,000 ft., are of a subtropical or warm temperate character, and are typical rain forests; they are damp, with lofty trees and luxuriant vegetation, resembling the tropical evergreen forests except that the prevailing species are different. The most characteristic trees of these forests are various species of *Quercus*, *Castanopsis*, *Eugenia*, and *Ficus*, some Magnoliaceae, many Lauraceae, *Ilex*, *Ternstroemia japonica*, *Bucklandia populnea*, *Ostodes paniculata*, and others. There is often a dense undergrowth of shrubs, climbers, and herbaceous plants, and the ground is sometimes covered with *Strobilanthes*. Grass is rarely found as a soil-covering.

In the drier hill forests the trees are not so tall as those of the damp hill forests, and at the higher elevations they become stunted, with low rounded crowns and short boles, forming the type known as elfin-wood. The vegetation of the drier hill forests is less luxuriant than that of the moist forests, and the climbers are neither so numerous nor so large. There is an undergrowth of shrubs and often of bracken fern (*Pteris aquilina*), or a soil-covering of grass where the crop is open. These forests are composed of various species of *Quercus* and *Castanopsis*, with *Eurya*, *Schima Wallichii* and *S. Noronhae*, *Ternstroemia japonica*, *Bucklandia populnea*, *Alnus nepalensis*, several Lauraceae and many Ericaceae, including species of *Agapetes* and *Vaccinium*, *Rhododendron arboreum* and other species, *Gaultheria fragrantissima*, and *Pieris ovalifolia*.

The pine forests (*Pinus Khasya*) are found for the most part at elevations of over 4,000 ft., mainly in the region of the drier evergreen forests; the pine forms pure crops of considerable extent, but is also found scattered in broad-leaved forests. A more detailed description is given under *Pinus Khasya*. The other Burmese pine, *P. Merkusii*, belongs properly not to the region of the evergreen forests but to that of the deciduous dipterocarp forests at lower elevations than *Pinus Khasya*.

(*g*) The mixed deciduous forests are, economically speaking, the most important forests of Burma, in that they are the home of the teak and many other valuable timber trees. They are found for the most part in places where the rainfall varies from 40 to 120 in., but they extend into regions of heavier rainfall, while in regions of less than 40 in. they exist as dry forms merging into thorn forest. The mixed deciduous forests, other than the drier forms, are typical monsoon forests. Most of the trees are leafless for a considerable part of the hot season and do not put on their new foliage till well on in that season or even till the beginning of the rainy season. Many distinct forms of mixed deciduous forest may be distinguished, but for our purpose it will be sufficient to distinguish three main forms: (i) upper mixed forests, (ii) lower mixed forests, and (iii) dry mixed forests. The terms upper and lower mixed forests are those employed by Kurz in his description of the forest vegetation of Pegu, and are well understood locally: a somewhat more detailed description of them than is given here will be found under *Tectona grandis*.

(i) Upper mixed forests are situated on well-drained hilly or undulating ground, and are usually characterized by the presence of bamboos in quantity. Two main sub-types are distinguishable, namely moist and dry mixed forest, these being determined largely by the species of bamboo present. In the Pegu Yoma the typical bamboo of the moist forests is *Bambusa polymorpha*, with *Cephalostachyum pergracile* in its more luxuriant form: in the more northerly parts of Upper Burma *B. polymorpha* is replaced by *Dendrocalamus Brandisii*, *D. Hamiltonii*, *D. membronoceus*, and other bamboos. The prevailing bamboo of the dry mixed forests is *Dendrocalamus strictus*, but *Cephalostachyum pergracile* in somewhat stunted form extends into fairly dry forest; *Thyrsostachys Oliveri* in Upper Burma is somewhat similar in habit to *Cephalostachyum*, though if anything it frequents rather drier forest. *Bambusa Tulda* extends into dry as well as moist forest. Many of the tree species are common to both dry and moist forest, though as a general rule their growth is superior in the latter. Among these species are *Tectona grandis*, *Xylia dolabriformis*, *Terminalia tomentoso*, *T. belerica*, *Homolium tomentosum*, *Adina cordifolia*, *A. sessilifolia*, *Stephegyne diversifolio*, *Bombax insigne*, *Gmelina arborea*, *Berrya Ammonillo*, *Vitex globrata*, *Odina Wodier*, *Anogeissus acuminata*, and *Spondias mangifera*. More characteristic of the moister forests are *Dipterocarpus alotus*, *Logerstroemia Flos-Reginae*, and *L. tomentosa*, while in the drier types *Acacia Catechu*, *Pterocarpus macrocarpus*, *Terminolia Chebula*, *Pentacme suavis*, and other species make their appearance. A special form of dry forest, containing few or no bamboos, is that known in the Pegu Yoma as *thitkyin*, in which the characteristic trees are teak, *Xylia*, *Terminalia tomentosa*, *Homalium tomentosum*, and *Lagerstroemio Flos-Reginae*, with an undergrowth often consisting of thorny twiners: there is sometimes a dense advance growth of *Xylia*.

(ii) Lower mixed forests occur on flat alluvial ground, and are characterized generally by the scarcity or absence of bamboos. Teak occurs in well-drained areas, and is sometimes very plentiful, attaining large dimensions. *Xylia dolabriformis* likewise occurs only on well-drained areas. Lower mixed forests vary greatly in character and composition. Among the commoner trees of the more typical lower mixed forests, besides the two mentioned, are *Lagerstroemia Flos-Reginae*, *L. tomentosa*, *Dipterocarpus alatus*, *Terminolia tomentosa*, *T. belerica*, *T. Chebula*, *Adina cordifolia*, *A. sessilifolia*, *Stephegyne diversifolia*, *Odina Wodier*, *Careya arborea*, *Dillenia pentagyna*, *Dalbergia cultrata*, *D. purpurea*, and *Anogeissus ocuminata*. Where these forests become open owing to excessive felling, severe fires, or inundation, they become savannah forests, in which the trees are scattered in an expanse of coarse grass; in these savannah forests, among the more typical trees in moist tracts are *Butea frondosa* and *Albizzia procera*. The lower mixed forests merge in places into tropical evergreen on the one hand or into *indaing* (deciduous dipterocarp forest) on the other, there being varying transition stages. There are also special types of lower mixed forest where certain trees become gregarious, for instance ***Terminalia tomentosa*** var. *macrocarpa* on clayey ground, forming open savannah forest resembling *indaing*, with a soil-covering of grass; stunted ***Dalbergia cultrata*** and *D. purpurea* may also form a special type on stiff clayey ground. Another form of savannah forest on stiff alluvial soil is that composed largely of species of *Gardenia* and *Randia*. These savannah types ought strictly speaking to be classified separately, but they merge so frequently into lower mixed forest that they can be conveniently dealt with along with it in a brief description like the present one.

(iii) Dry mixed forests, which are found for the most part where the rainfall is between 35 and 60 in., represent various transition forms between the usual mixed deciduous or monsoon forest on the one hand and thorn forest or deciduous dipterocarp forest on the other. They are found typically on the fringes of the dry zone, although they enter that zone, and also occur some distance outside it. The character and composition of the forest varies considerably. Many of the trees of the upper and lower mixed deciduous forests are found in these dry types, but they are stunted, while certain typical trees of the dry zone occur in addition. The crop is usually of an open nature, and merges into dry savannah forest. These dry types of forest are not wholly climatic; they may be due to dry hard or shallow soil. The typical bamboo is *Dendrocalamus strictus*, and among the commoner trees are ***Terminalia tomentosa***, ***T. Oliveri***, ***Tectona Hamiltoniana***, ***Pentacme suavis***, ***Shorea obtusa***, *Phyllanthus Emblica*, *Acacia Catechu*, *Pterocarpus macrocarpus*, ***Millettia*** spp., *Dalbergia Oliveri* (local), *D. cultrata*, *Cassia renigera*, ***Bauhinia variegata***, *B. racemosa*, *Diospyros burmanica*, and sometimes stunted teak and *Xylia dolabriformis*.

(*h*) The deciduous dipterocarp forests of Burma, locally known as *indaing*, are a characteristic feature of the forest vegetation of the province, and cover large areas. They are found most commonly on laterite, but occur also on sandy and gravelly soil or on gravelly clay. In the normal type of *indaing* the dominant species is *Dipterocarpus tuberculatus*, which grows gregariously, and with it are associated *Pentacme suavis*, *Shorea obtusa*, *Melanorrhoea usitata*, *Buchanania latifolia*, *Diospyros burmanica*, and other trees characteristic of this type of forest. The forest is usually of a somewhat open type, and there is frequently a soil-covering of grass, with shrubs such as *Indigofera*, *Flemingia*, *Desmodium*, and others, or stretches of the dwarf palm ***Phoenix acaulis***. Open *indaing* forest is of the true savannah type. A form of *indaing* in which *Dipterocarpus tuberculatus* is absent is that which occurs frequently on ridges and in other dry localities; here the dominant species is *ingyin* (*Pentacme suavis*), which is frequently associated with ***Shorea obtusa*** and other trees characteristic of *indaing*. These *ingyin* forests extend to the dry zone of Upper Burma, where the rainfall is less than 40 in. In the hills ***Dipterocarpus tuberculatus*** is often replaced by ***D. obtusifolius***, and ***Pinus Merkusii*** becomes a constituent species of some of the dipterocarp forests of the hills of Martaban and Tenasserim, while farther north ***P. Khasya*** enters these forests at their upper limits. A more detailed account of these deciduous dipterocarp forests will be found under *Dipterocarpus tuberculatus*, *D. obtusifolius*, and *Pentacme suavis*.

(*j*) The thorn forests of Burma are practically confined to the dry zone, where the rainfall varies from 23 to 40 in. In general appearance these forests resemble the thorn forests of the Indian Peninsula; they are of an open character and consist largely of thorny species, together with some characteristic unarmed trees, while on dry shallow soils they are reduced to the condition of open scrub. Among the commoner species of trees and shrubs are *Acacia Catechu*, *A. leucophloea*, *Dichrostachys cinerea*, *Tectona Hamiltoniana*, *Terminalia Oliveri*, *Capparis burmanica*, *Phyllanthus Emblica*, *Zizyphus Jujuba*, *Flacourtia Cataphracta*, *Carissa spinarum*, *Gardenia turgida*, *G. sessiliflora*, and *Limonia acidissima*.

12. *The Andamans.* The forests of the Andamans resemble those of Burma in general features; they differ to some extent in individual species, though many species are identical. The climate of the Andamans is warm and equable. The rainfall at Port Blair is 118 in., but judging by the aspect of the forests it is probably somewhat less in the North Andaman. The main types of forest in the Andamans are (*a*) mangrove forests, (*b*) beach forests, (*c*) evergreen forests, (*d*) semi-evergreen and deciduous forests, and (*e*) diluvial forests.

(*a*) The mangrove forests are of the usual type of mangrove swamp on muddy flats between high and low tide limits at the mouths of creeks and in sheltered backwaters. The outer limits of the mangrove swamp, nearest the sea, are composed mainly of *Rhizophora mucronata* and *R. conjugata*, while farther from the sea these species gradually give place to *Ceriops Candolleana*, *Kandelia Rheedii*, *Bruguiera gymnorhiza*, *B. parviflora*, *Carapa obovata*, *C. moluccensis*, *Cynometra ramiflora*, *Lumnitzera racemosa*, *Sonneratia acida*, and other species. On the banks of creeks or in places farthest from the sea and only reached by the highest tides are found *Heritiera littoralis* and *Aegiceras majus*.

(*b*) Beach forests take the form of comparatively narrow strips along raised beaches of sand, shells, and coral above high-tide limits. Among the commoner trees and shrubs of this type of forest are *Mimusops littoralis*, which sometimes forms pure belts, *Calophyllum Inophyllum*, *Terminalia Catappa*, *Erythrina indica*, *Pongamia glabra*, *Heritiera littoralis*, *Thespesia populnea*, *Afzelia bijuga*, *Hibiscus tiliaceus*, *Odina Wodier*, *Pandanus* sp., and *Ximenia americana*.

(*c*) Evergreen forests are confined for the most part to the ridges and upper slopes of the hills. In the South and Middle Andamans their distribution is further determined by the presence of micaceous sandstone, which favours the growth of this type of forest. The most characteristic trees of the evergreen forests are several species of *Dipterocarpus*, including *D. turbinatus*, *D. alatus*, *D. incanus*, and others, *Hopea odorata*, *Planchonia andamanica*, *Artocarpus Chaplasha*, *A. Lakoocha*, *Mesua ferrea*, *Myristica Irya*, *Calophyllum spectabile*, *Albizzia Lebbek*, *Diospyros Kurzii*, and *Podocarpus neriifolia*. There is a dense undergrowth of canes and other climbers, including the climbing bamboo *Dinochloa andamanica*.

(*d*) Semi-evergreen and deciduous forests occupy as a rule the lower slopes and undulating ground between the mangrove or beach forests and the evergreen forests, but in the South and Middle Andamans their distribution is also determined by the geological formation, since they are found almost entirely on metamorphosed and indurated clay and shale, conglomerate, quartzite, limestone, and hard coarse-grained sandstone. On hot southerly slopes these forests become typically deciduous, but elsewhere they are commonly of a semi-evergreen character. The most important timber tree of these forests is the padauk (*Pterocarpus dalbergioides*), and with it are found *Lagerstroemia hypoleuca*, *Terminalia bialata*, *T. Mannii*, *Albizzia Lebbek*, *Bombax insigne*, *Odina Wodier*, *Sterculia* spp., *Careya arborea*, and *Adenanthera pavonina*, as well as many of the trees of the evergreen forests. The undergrowth consists mainly of shade-bearing shrubs and small trees, with some palms and canes, but it is not so dense and impenetrable as in the evergreen forests.

(*e*) The diluvial forests occur on diluvial deposits of deep sandy soil lying between the mangrove forests and the hills. They contain trees of both the evergreen and semi-evergreen types, including *Dipterocarpus* spp., *Lagerstroemia hypoleuca*, *Bombax insigne*, *Terminalia bialata*, *T. Catappa*, *Sterculia alata*, and *Pterocarpus dalbergioides*. There is a dense impenetrable undergrowth of climbing bamboo, canes, and creepers, but as the mangrove swamps are approached the bamboos and canes disappear and the undergrowth consists largely of palms such as *Phoenix paludosa*, *Licuala*, and *Areca triandra*, while littoral species of trees such as *Heritiera littoralis* and *Cynometra ramiflora* make their appearance.

OECOLOGICAL FACTORS AND CLASSIFICATION IN RELATION TO INDIAN FORESTS. The foregoing brief account of the forest vegetation of India is sufficient to indicate that the various types of forest may be due primarily either to climatic or to edaphic factors, the latter term denoting factors connected with the soil as apart from the climate. It is now generally accepted by plant-geographers that the differentiation in the earth's vegetation is controlled by three main factors, temperature, atmospheric precipitation (including winds, which are desiccating agents), and soil: temperature and climatic humidity determine the flora and the vegetation, while changes of soil produce changes in the plant communities from place to place over areas of greater or less extent where the climate remains unchanged. Climatic and edaphic factors, however, cannot be considered separately in examining plant communities, which are the result of a combination of both. Climate is responsible for wide differences in the forest vegetation, such for instance as exist between the semi-desert flora of the north-western dry region and the tropical evergreen forest flora of the west coast of India, or between the latter and the temperate evergreen forest of high altitudes; the dominating factor in the former case is rainfall and in the latter temperature. Climate, however, is not responsible for the marked differences in plant communities which are so frequently observed in adjacent regions where the climatic conditions are identical. Take for instance the sharp line of division between the sal and teak forests of the Indian Peninsula, or the occurrence in Burma of that distinctive type of dipterocarp forest known as *indaing*, which is found over areas of greater or less extent alternating with mixed deciduous or evergreen forest, or the prevalence of mangrove forests on mud flats within tidal limits. In these three instances edaphic factors predominate in determining the character of the plant communities.

The various forest types of India can generally be referred to one or other of the woodland formations recognized by oecologists and plant-geographers, whose classifications have been based for the most part on the amount of water available for growth. For our present purpose we may follow Schimper's [1] broad classification of formations into two main oecological groups—(i) climatic or district formations and (ii) edaphic or local formations; these we may proceed to consider in turn in so far as they relate to India.

(i) *Climatic formations.* The three main types of climatic formation—woodland, grassland, and desert—are admirably represented in India. There the constant struggle for supremacy between woodland and grassland, in which conditions produced by the destructive action of man tend to favour the latter against the former, is strongly in evidence. Thus the clearing of forest in many cases results in the usurpation of the ground by grass; fire and grazing frequently have the same effect, and when these are combined with the clearing of forest by man the effect is the more marked. Where desert conditions are approached the types of woodland and grassland are stunted, and the struggle between them ceases, the struggle of both being against adverse climatic conditions. Deserts are oecologically speaking open formations, whereas woodland and grassland are closed formations; in the two latter there is a constant struggle for space, whereas in deserts there is much unoccupied space, a large proportion of the seed failing to germinate and numbers of seedlings perishing.

It is not easy to determine within definite limits the climate necessary to produce different types of woodland. Schimper notes that the higher the temperature the greater the rainfall necessary to produce hygrophilous trees: in the tropics these require a rainfall of at least 150 cm. (about 60 in.), whereas in cool regions of the temperate zone a rainfall of 60 cm. (about 24 in.) is sufficient. Soil factors, however, greatly modify any general statement of this kind, and the presence of water in the soil would mitigate to a large extent the effect of a small rainfall. In the dry plains of the Punjab irrigation has converted the natural semi-desert scrub into forest of a tropophilous type. Brandis says that in India really successful forests occur only where the rainfall is 40 inches and over, and that a luxuriant vegetation is limited to localities where the rainfall is much greater. Deserts, as Schimper notes, occur where the rainfall is never over 300 mm. (about 12 in.) and is usually much less: this definition of a desert climate applies to Sind, Baluchistan, the south-west Punjab, the southern part of the North West Frontier Province, and western Rajputana. Deserts are found for the most part outside the tropical lines: they are characterized by summer temperatures which are among the highest in the world, as well as by great atmospheric dryness, which acts in the same way as heat.

The chief climatic woodland formations in India are either tropical or temperate, the latter owing their existence primarily to elevation. In India Schimper's tropical woodland climatic formations, rain forest, monsoon forest, savannah forest, and thorn forest, are well exemplified: their main characters are as follows:

---

[1] A. F. Schimper, Plant Geography upon a Physiological Basis, Eng. ed., 1903.

Rain forest is the evergreen forest characteristic of warm tropical regions with a heavy rainfall and high atmospheric humidity. The rainfall is at least 200 cm. (about 80 in.), but is often much greater. The dry season is usually not prolonged, or where there is a prolonged dry season this forest occupies moist situations. The vegetation is luxuriant, the forest often consisting of two or more tiers, the trees of the highest tier being at least 100 ft. high and often much taller. The species are very numerous, and are chiefly or entirely evergreen; gregariousness is strikingly absent. Many of the trees have plank buttresses at the base; they have as a rule comparatively thin smooth bark and are only sparingly branched. The leaves are of very diverse forms, often firm, leathery, and glossy, seldom finely pinnate or with a thick covering of hairs. The forest is rich in thick-stemmed climbers, climbing palms, and woody as well as herbaceous epiphytes. Tropical rain forest is well developed on the west coast, in the moister parts of Burma, in Chittagong, Arakan, the Andamans, and the eastern sub-Himalayan tract and lower hills.

Monsoon forest occurs in regions where the rainfall exceeds 180 cm. (about 70 in.) but where there is a prolonged dry season. The forest is more or less leafless during the dry season; the trees are tropophilous in character and usually less lofty than in rain forest. This forest is rich in woody climbers and herbaceous epiphytes, but poor in woody epiphytes. The typical monsoon forest of Schimper's definition comprises the moister and more luxuriant forms of mixed deciduous forest which are well developed in the west coast region, in the moister parts of the sub-Himalayan tract, and in Assam, Chittagong, Arakan, Burma, and the Andamans. In the Indian region, however, monsoon forest answering the description in every respect occurs in regions with a rainfall of not more than 50 in., and perhaps as low as 40 in.; such forest is well developed in the sub-Himalayan tract east of the Jumna, as well as in parts of Chota Nagpur, Orissa, the Central Provinces, the Circars, and other localities.

Savannah forest is more or less leafless during the dry season, rarely evergreen; it is open and park-like in appearance, very poor in undergrowth, climbers, or epiphytes, and rich in terrestrial herbs, especially grasses. The trees are xerophilous in character and are usually less, often much less, than 65 ft. high. This formation comprises many different types of forest in India, including the opener types of mixed deciduous forest in the Peninsula, the sub-Himalayan tract, and Burma, as well as open grassy types of sal forest and of Burmese *indaing* forest.

Thorn forest is similar to savannah forest as regards foliage and height of trees, but is more xerophilous. Thorny plants are always plentiful; the forest is rich in underwood and slender-stemmed climbers, but poor in terrestrial herbs, while epiphytes are usually absent. Thorn forest is well developed in the drier parts of the Indian Peninsula and the sub-Himalayan tract, in the semi-desert regions of north-western India, and in the dry zone of Upper Burma.

Among the tropical woodland formations of minor importance may be mentioned the xerophytic evergreen bush forest of the Carnatic region: this formation is characteristic of localities where the rainfall is small but where there is no prolonged dry season.

At temperate elevations climatic formations of a different kind are met with. Temperate rain forest, which occurs in cool regions with a heavy rainfall, resembles tropical rain forest in general character, being hygrophilous and largely evergreen, though less luxuriant and not so rich in species: magnolias, laurels, and other evergreens are characteristic. This formation is developed at moderate elevations in the eastern Himalaya and in the moister hill regions of southern India, Assam, and Burma. In the eastern Himalaya above the rain forest the vegetation becomes tropophilous, many of the trees losing their leaves in winter. In the western Himalaya no true rain forest is found: the climate is drier and the vegetation is tropophilous, or in the drier regions xerophilous.

Of the west Himalayan evergreen oaks *Quercus incana*, *Q. semecarpifolia*, *Q. Ilex*, and *Q. lanuginosa* show decidedly xerophytic characters in their stiff leathery leaves with a dense felty covering of hairs on the lower surface. The conifers, which are a characteristic feature of temperate elevations, particularly in the Himalaya, constitute special types of forest. Warming[1] states that evergreen conifers are pronounced xerophytes when judged by their morphology, anatomy, and physiological characters: Schimper, however, rightly points out that it is not admissible to consider all conifers as xerophytes. Coniferous woodland, so far as Indian temperate species go, may be regarded as either xerophilous or tropophilous; in the former class may be placed *Pinus longifolia*, *P. Gerardiana*, the junipers, and probably *Cupressus torulosa*, while among tropophilous species may be placed *Pinus excelsa*, *Cedrus Deodara*, *Abies*, *Picea*, and *Taxus baccata*.

(ii) *Edaphic formations.* Edaphic woodland formations, which are due primarily to soil conditions, are well represented in India. The most important soil factor, at all events so far as Indian formations are concerned, is undoubtedly water; the mechanical texture of the soil and subsoil is also of great importance, but this factor operates to a large extent in its relation to the water content of the soil. Thus a fine-grained clay absorbs water slowly, has a high water capacity—that is, it is capable of holding a large percentage of water in proportion to its volume—and owing to its impermeability has great retentive power; a coarse sand, on the other hand, has a low water capacity and quickly parts with its water. Certain special formations, for instance those on saline soils in arid regions and along the coast, are due to the presence of soluble salts in quantity. Among edaphic formations whose existence is obviously due to the presence of water are fringing forests along the banks of rivers or lakes; these forests are maintained by the infiltration of water in the soil, or in some cases by periodical inundation. Among the best examples are the riverain forests along the Indus in Sind, consisting of *Acacia arabica*, *Tamarix dioica* and *T. Troupii*, *Populus euphratica*, and *Prosopis spicigera*. All but the last named of these species are incapable of surviving long in this arid region away from the influence of the river water. Along the banks of rivers in the dry parts of the Deccan, again, *Acacia arabica* grows gregariously, and gradually disappears on the higher and drier ground away from the rivers. Among other species characteristic of the fringing forests along rivers are *Salix tetrasperma*, *Putranjiva Roxburghii*, and *Trewia nudiflora*. It is, however, not always safe to attribute the existence of riverain forests solely to the presence of water. The characteristic riverain forests of *Dalbergia Sissoo* and *Acacia*

---

[1] Eug. Warming, Oecology of Plants, Eng. ed., 1909.

Catechu in northern India appear to owe their existence not so much to the presence of water in the soil as to the favourable conditions for the germination of the seed and the development of the young plants which are met with in these open riverain tracts; these conditions are loose porous soil, complete exposure to light, and absence of heavy weed-growth. This is apparent from the fact that these species thrive well in these regions away from rivers, and spring up readily, even in comparatively dry tracts, provided conditions for germination and development are suitable. Swamp forests are due to the presence of water, often more or less stagnant and lying in depressions on an impermeable soil. The mangrove formation of tropical littoral regions is a special form of swamp forest.

There are many edaphic formations in which water is the deciding factor, but where this factor is not obvious at first sight because it is governed by the mechanical texture of the rock and subsoil. In hill regions variations in the forest formation are observable with changes of aspect and configuration, where the underlying rock does not change; the more xerophilous species occupy the hotter aspects and the drier ridges, while the more hygrophilous species occupy the cooler aspects and moister depressions. Soil-moisture, as affected by aspect and configuration, is thus an important factor in determining the forest formation, but it may induce other important factors, such as a luxuriant growth of weeds in the moister localities, producing a struggle for existence which favours the establishment of certain species against others. The nature of the underlying rock and of the soil and subsoil is often found to have a very decided influence on the forest vegetation, but investigation will often, if not in most cases, show that its capacity for absorbing and retaining moisture is the dominant factor which influences the forest vegetation.

In the region of the sal (*Shorea robusta*) the presence of this important gregarious tree is determined to a great extent by the hygroscopicity of the soil. In the sub-Himalayan tract it is invariably absent from the recent sand and shingle of dry river-beds as well as from swampy ground, while on loamy soils it becomes the dominant tree over large tracts. In the Indian Peninsula it is found on various geological formations, but is almost entirely absent from the Deccan trap, where its place is taken by the teak; the soil overlying this rock is usually shallow, and in the dry season the amount of moisture retained in the soil and subsoil is insufficient for the survival of the sal. In a comparatively dry climate or situation, this species may be absent from a geological formation which it frequents in a moist climate or situation, and this applies to many other species.

In the South and Middle Andaman islands the relative distribution of evergreen forest and semi-deciduous padauk-bearing forest appears to be determined largely by the geological formation. The former occurs almost entirely on grey, usually soft, non-calcareous micaceous sandstone, while the latter is found chiefly on indurated clay and shale, conglomerate, crystalline limestone, and hard, coarse, often metamorphosed sandstone.

In the western Himalaya *Pinus longifolia*, a xerophytic species, is frequently found on quartzite, which is too dry to support the majority of species, and the presence of this rock in some localities determines the prevalence of the pine.

Laterite is an important geological formation in the Indian region, and from our point of view is of particular interest in that it supports very special types of forest vegetation. This rock, which is common in tropical countries, is a silicate of alumina very rich in hydrate of iron, red or dark yellow in colour, and poor in nutritive substances. It dries rapidly, but this does not seem to be due always, as is sometimes stated, to great permeability. Diluvial laterite is certainly permeable, and in general the permeability depends on the degree of disintegration: hard laterite, however, dries quickly owing chiefly to the rapid run-off of water from its surface, and to the fact that the soil overlying it is usually shallow. Hard weathered laterite is particularly unfavourable to forest vegetation, though laterite which is partially decomposed or mixed with soil derived from the decomposition of other rocks is by no means unfavourable. The most characteristic forest occurring on laterite is the deciduous dipterocarp formation of Burma known locally as *indaing* and consisting of *Dipterocarpus tuberculatus*, *Shorea obtusa*, *Pentacme suavis*, *Buchanania latifolia*, *Melanorrhoea usitata*, and certain other characteristic trees (see under *Dipterocarpus tuberculatus*). In the Indian Peninsula one of the commonest trees on laterite is *Cleistanthus collinus*, which grows remarkably well where the rock is in a decomposing state; other species frequently found on this rock are *Phyllanthus Emblica*, *Buchanania latifolia*, *Terminalia tomentosa*, and *Chloroxylon Swietenia*, while *Gardenia lucida* occurs in some localities on a mixture of clay and laterite. On the west coast *Xylia xylocarpa* is found growing gregariously on laterite.

A special type of soil which is found over large tracts in the Indian Peninsula is that known as black cotton soil. Dark or nearly black in colour, and containing a large proportion of clay, this soil has great capacity for absorbing water like a sponge in the rainy season, while it shrinks in the dry season, with the result that it becomes traversed in all directions by deep cracks: it is frequently, but by no means invariably, associated with trap rock. Black cotton soil is one of the most important agricultural soils of India, the great bulk of the cotton crop being grown on it. It is, however, unfavourable to forest growth, and the number of tree species found on it is comparatively small. Among the more characteristic trees are *Acacia arabica*, *A. Catechu*, *A. leucophloea*, *A. eburnea*, *Butea frondosa*, *Ougeinia dalbergioides*, *Cassia auriculata*, *Dichrostachys cinerea*, *Balanites Roxburghii*, *Terminalia tomentosa*, *Zizyphus Jujuba*, *Soymida febrifuga*, and among introduced species *Albizzia Lebbek* and *Azadirachta indica*. Teak in stunted form is sometimes found on this soil. When closed to grazing black cotton soil produces a heavy crop of grass, chiefly species of *Eragrostis* and *Paspalum*.

Calcareous soils are met with in various forms. Limestone rock usually has poor water-absorbing properties, particularly if it is weathered and has little depth of soil over it; in dry localities such rock supports xerophilous types of vegetation. The same applies to fine-grained calcareous soils deficient in organic matter, but where such soils are rich in organic matter and the climate is moist the vegetation becomes hygrophilous. Warming[1] points out that although the characteristics of the lime flora are clear and distinct the influence of lime upon vegetation has been over-estimated. He notes that it has been definitely established that the amount of lime in itself, in so far as it does not operate physically, cannot be the cause of differences in the flora, for not only can calcicolous plants be cultivated in a soil poor in lime, but silicicolous plants can grow vigorously in pure lime-water if the aqueous solution be otherwise poor in dissolved salts; lime soils as a rule are rich in soluble mineral substances, and this excludes plants characteristic of minerally poor soils. It may be noted here that *Cupressus torulosa*, which is characteristic of limestone regions in the Himalaya, grows well when planted in ordinary loam on other geological formations. *Pinus longifolia*, on the other hand, may be regarded as essentially silicicolous, flourishing best on sandy soils, but nevertheless it grows naturally on hard limestone rocks in the outer hills of Hazara, although owing to the physical characters of the rock the growth is poor except on northerly slopes where there is some depth of soil; that limestone is not unfavourable to *Pinus longifolia* provided the rock is not hard and the overlying soil is not shallow, is evident from the fact that the tree grows well in parts of the Kumaun hills on limestone where the rock is sufficiently soft and the soil is not too shallow.

---

[1] *Op. cit.*, p. 58.

Pans of concretionary lime, often mixed with clay, known as *kankar*, are of common occurrence in India, and are particularly unfavourable to forest growth, the lime forming a hard solid mass resembling masonry, and by its physical condition preventing the free development of the roots of trees; the forest vegetation is of an open, stunted, and xerophytic character. Calcareous tufa is found occasionally in the sub-Himalayan tract in the form of moderately hard deposits not far beneath the surface, and here again the forest vegetation becomes open and stunted; *Bombax malabaricum* and *Hymenodictyon excelsum* are often characteristic species, while *Shorea robusta*, which may be abundant in the neighbourhood, avoids ground where these deposits are at all superficial.

Saline soils, other than those due to proximity to the sea, are characteristic of regions of high summer temperature combined with deficient rainfall. In the dry season moisture evaporates from the surface layers of the soil, and in time there forms an accumulation of saline substances which the scanty rainfall is insufficient to remove, while the saline solutions in the lower layers of the soil ascend by capillarity, forming on evaporation a whitish alkaline efflorescence on the surface of the ground. Salts may be produced by the decomposition of rock minerals *in situ* or may be transported from a distance in solution. The degree of salinity is particularly high in heavy clay soils where the drainage is bad and there is little percolation, or in places where an impervious layer in the subsoil prevents free drainage; in well-drained porous soil the salts are removed in solution. As the degree of salinity of a soil increases vegetation diminishes until the soil becomes quite sterile. The chief salts are sodium carbonate, sulphate, and chloride; all are harmful to plant life, though sodium carbonate is the most noxious. Among the few trees which will grow on soil with a moderate degree of salinity are *Acacia arabica*, *Prosopis spicigera*, *Tamarix articulata*, and *Butea frondosa*. More halophilous still is the shrub *Salvadora persica*, while in soil which is strongly saline and yet not quite sterile *Salsola foetida* and *Suaeda fruticosa* are characteristic. After heavy rain patches of strongly saline soil often become covered with a growth of the grass *Sporobolus arabicus*, Boiss., which dries up and disappears soon after the rain is over.

The most successful methods of reclaiming saline lands are those which aim at improved drainage. Where water is plentiful perhaps the most satisfactory method is to dig deep open drains dividing the land into fairly large sections and to heap the earth up in the form of bunds round the sections. Each section is then well flooded with water, which percolates through to the drains and carries away the salts in solution. Flooding has to be repeated as a rule several times. In the Kistna delta saline lands in proximity to the coast are reclaimed by puddling in large quantities of straw and then flooding with water; the straw assists drainage. Dressing the soil with gypsum (sulphate of lime) has proved effective in some cases, the gypsum reacting on the sodium salts and producing less injurious substances. As gypsum is scarce in India, however, this method is too costly for general application. A method of planting *Acacia arabica* and *Prosopis spicigera* on saline lands, which has been attended with some success, is described under *Acacia arabica*.

The different types of littoral woodland are edaphic formations of a very special kind; the component species are essentially halophytic owing to the saline nature of the soil, and exhibit xerophytic structures because of its physiological dryness. Below high tide there is no forest vegetation on sandy and rocky sea-shores, but in estuaries and lagoons and along tidal creeks is found the mangrove formation, a special type of evergreen forest which is unlike any inland formation, and of which the component species have leathery leaves exhibiting xerophytic structures. On the higher ground farther from the sea and exposed only to the influence of spring tides is found a different type of forest, usually termed 'tidal forest', in which the principal tree in the Sundarbans and the Burma coastal regions is *Heritiera Fomes*. The mangrove and tidal forests are described in some detail under Rhizophoraceae and *Heritiera Fomes*. The trees are characterized by the possession of special adaptations for resisting the force of the wind and the tides, in the shape of stilt-roots or of anchor-roots descending from the stem and branches; special adaptations for the aeration of the roots in the muddy ground in which these trees grow are seen in the form of superficial roots, sometimes ribbon-shaped, spreading along the surface of the ground or bending out of the mud in the form of knees, while some species send up pneumatophores resembling inverted tent-pegs. The trees of beach forests, on old raised sandy and stony beaches above the reach of high tide, often exhibit xerophytic leaf structures, especially towards the outer edge of the littoral belt; this is seen in the thick and leathery leaves of *Calophyllum Inophyllum*, *Terminalia Catappa*, and *Barringtonia speciosa*, the succulent leaves of *Scaevola Koenigii*, the scale-like leaves of *Casuarina equisetifolia*, and the leaves, covered with a gummy varnish, of *Dodonaea viscosa*.

The examples of edaphic formations just given will serve to illustrate some of the more marked types of forests which depend for their existence mainly on edaphic conditions. These do not include the many variations to be found in ordinary forest soils varying from stiff clay to pure sand, the relative proportions of which may exercise a decided influence on the composition of the forest crop. The presence of certain species of trees on stiff clay or on pure sand does not necessarily indicate their preference for such soils; in many cases it indicates nothing more than their capacity for existing on them. Thus *Terminalia tomentosa*, *Butea frondosa*, *Stereospermum suaveolens*, and *Eugenia operculata* are often found on stiff clay, though they are by no means confined to it. *Dalbergia Sissoo* and *Acacia Catechu* grow freely on the pure sand and shingle of riverain tracts, but they thrive also on loamy soils, though the former species in particular will not tolerate heavy clay.

Abundant soil-moisture may have the same effect as reduction of temperature, a fact which is illustrated by the presence in moist localities in the sub-Himalayan tract, at elevations of about 2,000 ft. or even lower, of species which occur normally at temperate regions in the Himalaya at elevations of 4,000 to 8,000 ft. or more. Instances are *Quercus incana*, *Q. spicata*, *Celtis australis*, *Acer oblongum*, and *Hedera Helix*. The presence in such localities of temperate species is possibly due to the reduction of temperature consequent on active transpiration during the hot season, the loss of water being made good from the large supply available in the moist soil.

The importance of forest grasses as indicators of edaphic conditions has been demonstrated by Hole[1] in respect of the Dehra Dun valley and Saharanpur Siwalik tract. The oecological study of these grasses over defined tracts where the climatic conditions are constant will often lead to interesting and important results in demonstrating the suitability of different classes of soil for the growth of different species of trees, since there is often a marked parallelism between certain types of forest and of grassland respectively. Thus in the Dehra Dun and Siwalik tract the dominant grass on ground most favourable for the growth of sal is *Saccharum Narenga*. On dry shingle beds and in other places which are usually too dry to support sal, and on which forest of a dry mixed deciduous type is prevalent, the dominant grass is *Saccharum Munja*, while other common species are *Aristida cyanantha*, *Triraphis madagascariensis*, *Andropogon monticola*, and the dry form of *Saccharum spontaneum*: the parallel woodland formation on these dry shingle beds is forest of *Acacia Catechu* and *Dalbergia Sissoo*. In moist mixed forest, sometimes merging into swamp forest, *Erianthus Ravennae* is the dominant grass. *Imperata arundinacea* often denotes stiff badly drained clayey soil or denuded ground somewhat unfavourable to the growth of sal. *Phragmites Karka* and *Arundo Donax* are species indicative of ground which is too swampy for sal and for the great majority of trees; *Saccharum spontaneum* is also frequently prevalent on low-lying wet ground unsuitable for sal. *Anthistiria gigantea* frequents sal tracts, but may also indicate ground insufficiently drained for sal. Again, in the eastern sub-Himalayan tract, where the climate is moister, savannahs are of frequent occurrence. Here again the dominant grass on ground suitable for sal is *Saccharum Narenga*, and with it occur *Saccharum arundinaceum*, *Arundinella Clarkei*, *Erianthus fastigiatus*, and *Andropogon Nardus*. As before, *Imperata arundinacea*, though sometimes present on sal-bearing ground, may also indicate stiff badly drained clayey soil, while *Saccharum spontaneum* and *Anthistiria gigantea* may also be indicative of ground not sufficiently well drained for sal. *Phragmites Karka*, *Erianthus elephantinus*, and *Saccharum procerum* are characteristic tall grasses of the moist low-lying savannahs unsuitable for sal and supporting open forests of *Albizzia procera*, ***Bischoffia javanica***. ***Bombax malabaricum***, and other trees.

---

[1] R. S. Hole, On some Indian Forest Grasses and their Oecology, Ind. For. Mem. Bot., Ser. i. i, 1911.

Similarly, bamboos are good indicators of varying soil conditions, and in countries like Burma, where they form an important adjunct to some of the principal types of forest, they are of special interest in this respect (see under ***Tectona grandis*** and Bambuseae).

SOIL CONDITIONS. In the foregoing account of some of the edaphic formations of India mention has been made of certain classes of soil which have a decided influence on the character of the forest vegetation. Although it will be impossible here to enter into a detailed consideration of the properties of soils, there are certain questions connected with the soil which closely affect the origin, the distribution, and the stability of various forest crops.

The question whether the chemical or the physical characters of the soil exercise a more decisive influence on the distribution of plants is one which has been discussed by many writers, some of whom have supported the one point of view and others the other. Although due weight must be given to the importance of chemical influences in certain classes of soil, nevertheless the basis of oecological classification is a physical one, namely, the water content of the soil, which is in turn influenced by its physical characters, such as depth, consistency, and capacity for absorbing and retaining water. Some modern writers have devoted special attention to the study of so-called soil solutions, in which the moisture in the soil is regarded as a medium by which nutriment is conveyed to the roots of plants. It is not sufficient that a soil should contain the elements necessary to support plant life; it is equally necessary that these elements should be in a condition suitable for absorption by the roots of plants, that is, they should be in solution. Many desert or semi-desert soils are rich in nutriment, but in their natural condition are incapable of supporting any but the most xerophilous vegetation, although if irrigated they yield abundant crops. Where the degree of concentration of a soil solution tends to vary through some external influence such as wetting and drying, the soil is said to be anastatic, whereas soils which remain more or less constant in this respect are termed eustatic. The soils of bare or ploughed land are more anastatic than those of grassland and forest. In the majority of soils conditions of anastatism exist mainly near the surface, and a soil may be converted from a eustatic to an anastatic condition by special treatment such as ploughing, mulching, manuring, or liming, thus promoting new chemical reactions or altering the moisture conditions.

The soil at a depth at which the roots of forest trees mainly receive their nourishment is eustatic. Anastatic conditions can be set up artificially in practice to a depth of a few feet by drainage, and to a greater depth by irrigation, but so far as is known there is no reliable evidence in India of any marked change, within a short period of time, of soil conditions at any considerable depth below the surface owing either to the draining or the moisture-conserving action of forest growth of recent introduction. There is, however, striking evidence of sudden change in the soil conditions at some depth below the surface in years of abnormal drought, when even the most deep-rooted trees are killed for want of moisture. In the abnormal drought of 1907 and 1908 in the forests of the alluvial plains of Oudh the subsoil water-level fell in varying degree in different localities. In the forests of South Kheri the fall below normal level averaged 10 ft. In these forests the trees were found to be seriously affected over certain well-defined patches, and borings down to water-level showed that these patches coincided with the presence of thick deposits of pure sand, whereas in the intervening areas, where the damage was not so serious, the subsoil consisted mainly of clayey loam with only occasional thin deposits of sand. When the water-level sank owing to the deficient rainfall of two successive years the thick deposits of sand were unable to retain sufficient moisture to keep the more deep-rooted trees alive, and these died in large numbers. Sudden changes in soil conditions at some little depth are also seen in submontane regions where deposits of silt brought down by rivers in flood are accumulated to a depth of several feet, with the result that riverain forests die over considerable areas; the adverse conditions in this case are probably connected with the cutting off of the supply of oxygen from the roots of the trees by the accumulation of silt. This form of damage is not uncommon in the eastern sub-Himalayan tract. Riverain forests are sometimes killed through the shifting of the course of the river and the consequent diminution of the water content of the soil. In Sind forests of *Acacia arabica* have been killed in this way through the erection of bunds which have cut off the annual flood water. The abnormal inundation of forest not habituated to flooding may also result in the death of the trees.

The instances just quoted refer to altered soil conditions at a depth sufficient to affect the roots of mature trees; such instances may be regarded as exceptional, since the subsoil is normally in a eustatic condition. On the other hand, the surface soil, even in the forest, is much more subject to external influences, producing changes which may be gradual under natural conditions but which can be produced rapidly by artificial means. Thus the soil conditions at the surface of the ground may be totally different from those encountered at some depth. This fact is of great importance, since it implies that trees in their seedling stage may—in fact they very often do—encounter soil conditions differing radically from those encountered after the roots penetrate to some depth. It also implies that ground which supports a crop of adult trees may be incapable of supporting seedlings of the same species owing to adverse conditions in the surface soil which have been brought about by a process of change: this fact has a direct bearing on the question of woodland succession, referred to below. Nevertheless conditions in the surface soil may often be altered artificially by such means as exposure to the sun and air, burning, soil-aeration and conservation of soil-moisture by hoeing or ploughing, and other measures, and this fact is of special importance in its bearing on regenerative operations. It will thus be seen that the seedling stage, which is the most critical stage in the life of the tree, has to be considered in its relation to conditions prevailing in the surface layers of the soil, and in this respect the seedlings of trees encounter soil conditions approximating to those encountered by field crops rather than by adult trees, whose roots are for the most part situated at a depth where conditions are more eustatic than they are at the surface.

The four most important factors operating in the soil are water, temperature, mineral salts, and oxygen, and if any one of these factors is in defect the amount of it present regulates the growth of the plant, which is not influenced favourably by an excess of other factors. As regards the supply of oxygen to the roots of plants, prominence has in recent years been rightly given to the importance of thorough aeration of the soil. Mr. Hole has found that in the case of many soils the death or the annual dying back of seedlings of *Shorea robusta* is due to adverse conditions resulting from deficient aeration. He has shown by means of water cultures that water in itself is harmless, but that water held in contact with the soil of the sal forest soon becomes highly injurious to the roots of the seedlings, this injurious action being correlated with an accumulation of carbon dioxide and an impoverished supply of oxygen. Bad drainage tends to increase the adverse factor, whereas aeration of the soil tends to dissipate it, and experiments carried out in the forest in a locality where seedlings die back regularly have shown that this dying back can be prevented merely by hoeing the soil and thus promoting aeration. The stimulation of vigorous growth by means of soil-aeration is no less important in cases where seedlings are liable to die of drought in the dry season, since it enables the young plants to send down strong taproots into the moister layers of soil beneath the surface. The results obtained by Mr. Hole, a fuller account of which will be found under *Shorea robusta*, are of great importance not only in connexion with the regeneration of sal forests, but also as indicating the measures which are likely to prove successful in promoting favourable soil conditions in the case of other species. A system of improving the surface soil conditions by mulching, first introduced by Mr. Copleston in the forests of Kanara, has proved highly successful in the drier types of teak forest in saving seedlings which would otherwise perish in large numbers in the dry season: the process is described under *Tectona grandis*.

My own experiments in connexion with the study of seedlings of forest trees, the results of which are recorded in this work, have clearly demonstrated the beneficial effects of weeding, combined with loosening of the soil, as a means of stimulating the growth and promoting the survival of seedlings. These experiments have shown that even where no watering is carried out the growth produced by the removal of weeds and the aeration of the soil is in some cases almost, if not quite, as rapid as that produced by watering. Specific instances of the effect of weeding combined with loosening the soil will be found under *Azadirachta indica*, *Schleichera trijuga*, *Butea frondosa*, *Dalbergia Sissoo*, *Hardwickia binata*, *Bauhinia racemosa*, *Acacia Catechu*, *Albizzia Lebbek*, *Terminalia belerica*, *Eugenia Jambolana*, *Wrightia tomentosa*, *Cordia vestita*, and other species.

Recent work in the afforestation of dry barren denuded ravine lands in the Etawah district of the United Provinces has demonstrated in striking fashion the value of deep ploughing and sowing of tree seeds followed by repeated loosening of the surface soil, thereby promoting soil-aeration and conserving soil-moisture. By this means young crops of *Dalbergia Sissoo*, *Acacia arabica*, *Tectona grandis*, and other species, raised on ground which in its original state could hardly be more unpromising for tree crops, have shown phenomenal growth.

NATURAL REPRODUCTION. There is no branch of Indian forestry more important than the study of natural reproduction. The establishment of seedling reproduction is closely connected with conditions of seeding and germination and with the requirements of the seedling. Vegetative reproduction, although of less importance generally, may have special significance under certain conditions. Not only is the study of natural reproduction an essential preliminary to the adoption of correct silvicultural treatment for different kinds of forest crops, but it also serves to elucidate many problems connected with such interesting and important questions as invasion, woodland succession, and gregariousness. As a preliminary to the determination of the several factors which affect the establishment of seedling reproduction in any particular instance, it will be found necessary to consider three separate stages leading towards the production of a young natural crop: these stages are (1) flowering and fruiting, including the dissemination of seed, (2) germination, and (3) the seedling. We may here consider briefly some points of interest connected with these stages.

Flowering, fruiting, and germination. In many cases, and perhaps in the majority, the fertilization of the flowers of Indian forest trees appears to be carried out by insect agency, for many of the trees when in flower are visited by swarms of bees and other insects, and the flowers are often perfumed or showy, or exude nectar. Important exceptions are to be seen in the case of the conifers, which are fertilized by the agency of the wind, and produce pollen in large quantities. Certain showy flowers, notably those of *Bombax* and *Erythrina*, are fertilized by birds; it is noticeable that such flowers have a tendency to be red in colour.

The dissemination of seed is a subject which concerns natural reproduction very closely. Some writers place a much higher value than others do on the efficiency of wind as a distributing agent. In most cases winged or light seeds and fruits certainly rely on wind as the chief distributing agent, but the extent to which distribution takes place in the case of each species is by no means easy to determine from casual observation. Under ordinary conditions the heavier winged fruits and seeds, for instance the fruits of dipterocarps, are not conveyed in quantity to any great distance from the trees. In the case of Indian conifers, the winged seeds of the pines—other than *Pinus Gerardiana*—and the spruces, which escape singly from the cones, are ordinarily conveyed to greater distances than are those of the deodar and silver fir, whose seeds fall with the cone-scales when the cones break up on the tree. In the case of some pines, notably *Pinus longifolia*, the cone-scales open gradually; the cones are attached to the branches at various angles, and the seeds are not dislodged in any quantity without the aid of a stiff breeze, which ensures their spread to some distance. Seeds, such as those of *Bombax*, *Populus*, and *Salix*, which are embedded in silky down are carried by wind over considerable distances.

Water is the natural distributing agent of seeds of species growing in littoral regions. The fruits or seeds of such species often have special adaptations for floating, usually in the shape of floating tissue. *Terminalia Catappa* has floating tissue in the fruits, *Carapa moluccensis* has a large fleshy seed with a thick fibrous testa, *Sonneratia apetala* has a globose fleshy buoyant fruit, *Avicennia officinalis* has a large buoyant capsule, and *Heritiera Fomes* has a large starchy seed with a cavity between the cotyledons which ensures its buoyancy. Among inland species which are frequently found near streams and of which the fruits are buoyant, may be mentioned *Dillenia indica*, with large globose fruits the outer portion of which is formed of the persistent fleshy sepals, and *Trewia nudiflora*, with globose fruits having a fleshy mesocarp of floating tissue. Many of these water-borne seeds ripen during the rainy season when the streams are swollen, and this aids greatly in their dissemination. This applies not only to *Trewia nudiflora* but also to littoral species, for instance *Excaecaria Agallocha*, *Heritiera Fomes*, *Carapa moluccensis*, *Sonneratia apetala*, *Avicennia officinalis*, and others.

Birds and fruit-bats are disseminating agents in the case of many fleshy fruits. The effect of bird agency is nowhere more marked than in the case of the numerous species of *Ficus*, several of which start life as epiphytes in the forks or cavities of tall trees. Birds in some cases probably carry seeds to a considerable distance, as in the case of *Lantana*, and it is often difficult to account for the appearance in certain localities of isolated specimens of trees—for instance, *Carallia lucida* in parts of the sub-Himalayan tract—except by attributing it to the agency of birds.

Apart from their agency in effecting this dissemination of seeds, as in the case of *Zizyphus Jujuba*, *Spondias mangifera*, and other species, animals may exercise an important function in facilitating their germination. If the fruits of *Aegle Marmelos* are not opened by pigs, deer, and other animals the seeds usually, if not always, decay or are destroyed by insects before escaping from the fruit. Perhaps the most remarkable instance so far observed of such animal aid is that of the opening of the pods of *Cassia Fistula* by jackals, monkeys, and other animals, without which it is doubtful if the seed ever germinates before it is destroyed by insects. Seed of *Acacia arabica* ejected by goats and other animals which have eaten the pods germinates more freely than that which has not undergone this treatment. The assistance given by termites to the germination of *Dillenia indica* seed is described in dealing with that species.

Birds and animals, on the other hand, may exercise an adverse influence on natural reproduction by destroying seed in quantity; for instance, jays, nutcrackers, and flying squirrels at times do much harm in this respect in the oak and conifer forests of the Himalaya.

In many cases the nature of the seed indicates not only the conditions under which germination is facilitated or rendered possible but also the demands of the seedling. The seeds of many species which stand shade or require moisture in youth or later are large, heavy, and often smooth and rounded: such seeds tend to roll into moist depressions and ravines where the requirements of the young plant are provided for. Such are the seeds of *Mesua ferrea*, *Dysoxylum* spp., *Amoora Rohituka*, *Calophyllum* spp., *Aesculus indica*, and others. On the other hand, small light or winged seeds and fruits, which are disseminated far and wide, germinate freely on newly exposed mineral soil, and the seedlings require open places for their development and survival; accordingly natural reproduction springs up readily on landslips, abandoned cultivation, newly formed deposits in river-beds, areas recently overrun by fire, and similar places. Species belonging to this category, which are often, but not invariably, strong light-demanders, include *Tamarix* spp., *Cedrela* spp., *Bucklandia populnea*, *Dalbergia Sissoo*, *Terminalia myriocarpa*, *Anogeissus latifolia*, *Woodfordia floribunda*, *Wendlandia exserta*, *Anthocephalus Cadamba*, *Adina cordifolia*, *Stephegyne parvifolia*, *Duabanga sonneratioides*, *Rhododendron arboreum*, *Macaranga* spp., *Trema* spp., *Betula* spp., *Alnus* spp., *Salix* spp., *Populus* spp., *Casuarina* spp., and conifers with winged seeds. In the case of most seeds other than those of minute size or light weight, a covering of earth or débris greatly assists germination, and may be essential in dry situations in the case of seeds which ripen and fall some time before the beginning of the monsoon: this covering is commonly effected by the action of rain, and is greatly facilitated in loose soil.

The monsoon is the natural season for germination in the case of the great majority of Indian species, and seeds which are quickly perishable fall during or at the commencement of this season and germinate at once; this is seen in the case of the Dipterocarpaceae, *Mangifera indica*, *Eugenia Jambolana*, *E. operculata*, and many littoral species. Many seeds whose vitality does not last many months fall some little time before the monsoon and germinate when it begins. Some seeds, particularly those which are hard or are enclosed in a hard putamen, retain their vitality for at least a year, and under natural conditions frequently lie dormant for that period or longer. Such are the seeds of many Leguminosae, including *Cassia Fistula*, *Bauhinia malabarica*, *B. racemosa*, *B. purpurea*, *Acacia arabica*, *A. Farnesiana*, *Prosopis spicigera*, *Albizzia Lebbek*, *A. procera*, *A. stipulata* and other species, *Zizyphus Jujuba*, *Z. Xylopyrus*, *Sapindus detergens*, *Spondias mangifera*, *Gardenia turgida*, *Diospyros Melanoxylon*, *D. tomentosa*, *Cordia vestita*, *Tectona grandis*, *Fraxinus excelsior*, and *F. floribunda*. The seeds of the teak (*Tectona grandis*) are known to lie dormant in the ground sometimes for years.

The seedling. The seedling represents the most critical stage in the life of a tree. Conditions for seeding and germination may be entirely favourable, and natural seedlings may appear in countless quantities at the beginning of the rainy season, only to disappear largely or entirely within a comparatively short period of time owing to various causes, such as drought, bad soil-aeration, competition with weeds, shade, or other factors. Such a holocaust, which is a regular event in the case of many species, does not occur to the same extent throughout the life of an established crop after the seedling stage is passed, except for very special reasons such as the occurrence of abnormal drought. If the requirements of the seedling of any species are well understood the problem of the natural reproduction of that species is to a great extent solved, while the subsequent treatment of the crop is usually a comparatively simple matter. The whole system of management of a forest crop is fundamentally influenced by the steps necessary to establish reproduction, and it will therefore be readily realized that no branch of silviculture is of more importance than the study of the requirements of the seedlings of forest trees. Again, as will be explained below, problems of invasion, succession, and gregariousness have to be approached from the point of view of the seedling, for it is the establishment of the young plant that determines to a great extent, if not wholly, the occurrence of existing forest crops of various types, and in like measure regulates the transition from one type to another from place to place or during the course of time.

The size or form of the seedling often indicates the condition under which it passes its existence. In the case of many species with minute seeds the seedlings themselves are minute in their earlier stages, and in such cases an essential condition for their establishment is that they should spring up on clean and preferably porous soil, since owing to their minute size any competition or obstruction will prevent their development and establishment. Such seedlings are those of *Anthocephalus*, *Adina*, *Stephegyne*, *Duabanga*, *Rhododendron*, *Populus*, and others. A remarkable instance of the adaptation of the seedling to a special environment is to be found in the case of certain littoral species, for example *Carapa moluccensis* and *Heritiera Fomes*. The large fleshy cotyledons, which remain within the testa, are full of starchy nutriment. On germination a long leafless stem, resembling that of asparagus, and bearing only abortive scaly leaves, shoots up rapidly and attains a considerable length before any foliage leaves are produced. The nutriment in the cotyledons is thus employed for the rapid production of a stem which will elevate the foliage leaves above the level of the water which floods the ground periodically. Under natural conditions the seedling of *Quercus semecarpifolia*, the high-level oak of the western Himalaya, as a rule produces a shoot which remains leafless during the first season. Germination takes place about July, and a short growing season is followed by a period of autumn drought and a severe winter: the seedling therefore at once assumes a leafless winter form in order to withstand the climatic rigours to which it is exposed. A straggling branchy form in the seedling, often accompanied by the production of a long wiry taproot, is usually indicative of xerophytic habits, and may be seen in the case of seedlings of *Prosopis spicigera*, *Acacia* spp., *Zizyphus Jujuba*, and *Z. Xylopyrus*.

It is a well-known fact that in plants generally the amount of transpiration depends largely on the extent of the evaporating surface, that is, on the size of the leaves, as well as on their texture and disposition. The effect of external factors is clearly exhibited in the variation in the size of the leaves of seedlings of one and the same species, which is usually greater than in the case of adult trees. In many parts of India, however, perhaps the most important attribute of the seedling is the development of the root-system, since seedlings have to contend against the adverse influence of a long dry season, and the deeper the penetration of the root the less the risk of failure of the requisite water-supply during periods of drought: hence the importance of any measures which can be taken to promote a strong root-system during the first few months in the life of the seedling. Under conditions sufficiently far removed from the optimum, one of Nature's methods of assisting the survival of seedlings is to provide for the dying back, in whole or in part, of the stem of the young plant. This dying back often takes place for several years in succession, new shoots being produced year after year from the living tissues below the dead portion of the stem, usually from the collum. Meanwhile the root develops steadily, pushing its way down until it has established itself sufficiently, after which the stem ceases to die back and commences upward growth. The commonest cause of dying back is drought, since the phenomenon is seen most frequently in dry regions, where it takes place in the dry season; in this case dying back ceases when the root has penetrated to strata moist enough to make good the loss of moisture by transpiration. In the case of *Shorea robusta*, and possibly of other species also, another fruitful cause of dying back is bad soil-aeration operating during the rainy season (see under *Shorea robusta*). Dying back may also be the result of frost damage. The production at an early age of a strong taproot, with few or no lateral roots, appears to be a characteristic of seedlings which die back. The phenomenon is perhaps commoner than is usually supposed, and under certain conditions is characteristic of such widely different species as ***Shorea robusta, Bombax malabaricum, Pterocarpus Marsupium, P. santalinus, Butea frondosa, Hardwickia binata, Bauhinia racemosa, Acacia Catechu, A. Senegal, Terminalia tomentosa, Eugenia Jambolana* var. *caryophyllaefolia, Diospyros Melanoxylon, Santalum album, Tectona grandis,*** and ***Quercus semecarpifolia.***

Vegetative reproduction. In many species the production of suckers is an important aid to the perpetuation of the species, particularly in dry localities where conditions for seedling reproduction are adverse. One of the most noteworthy examples of this is seen in the case of ***Prosopis spicigera*** in the arid regions of north-western India, where seedling reproduction is incapable of establishing itself except in riverain areas and moist depressions; nevertheless on the more elevated and drier ground *Prosopis* survives, and has apparently survived for long periods of time, by means of sucker reproduction. This form of reproduction appears to be common in dry situations, though it is by no means confined to such places. Certain species, notably ***Diospyros Melanoxylon*** and *D. burmanica*. are remarkably tenacious of the ground they occupy owing to the vigour of their sucker reproduction: where they are present they are among the last species to disappear when land is cleared for cultivation, and land which has been cultivated for a few years and then abandoned becomes covered with sucker growth of these trees. There are certain other species which are nearly if not quite as tenacious, for instance *Butea frondosa, Ougeinia dalbergioides, Acacia dealbata*, and others. Among bamboos *Melocanna bambusoides* displays similar tenacity in the manner in which culms are sent up from portions of the rhizomes left in the ground on land cleared for cultivation. The list of species producing suckers is a long one. Certain natural orders exhibit a striking tendency to reproduce in this way, notably the Leguminosae (***Dalbergia, Ougeinia, Butea, Cassia, Xylia,*** *Prosopis, Dichrostachys, Albizzia*, some species of *Acacia*, and many others), the Rosaceae, and the Bignoniaceae (***Stereospermum, Heterophragma, Millingtonia,*** *Oroxylum*).

Vegetative reproduction is not confined to the continuance of the species by means of suckers, but may be taken to include also the power to persist by means of new shoots from the base or otherwise when coppiced or when subjected to cutting, lopping, burning, browsing, or other forms of injury. This power is possessed to a considerable degree by the teak, which in parts of the Indian Peninsula is sometimes almost the sole survivor in areas subjected to every form of maltreatment.

INVASION, SUCCESSION, AND GREGARIOUSNESS. Even to the most casual observer the fact is often brought home that certain types of forest are of a temporary kind, and after occupying the ground for varying periods of time give way in the natural course of events to other types, this change being sometimes accelerated by a change in external conditions. A study of these changes is of great importance to the forester, for an appreciation of their significance will often afford an indication of the kind of forest crop which can be grown in a given locality. It may be said in general that every existing natural forest crop has been brought into being by a process of invasion, followed in many cases by succession, the struggle for existence determining its composition to a large extent. 'Invasion' has been defined as the movement of plants from one area to another of a different character and their establishment in their new home. Among examples of invasion may be mentioned the following: (1) *Macaranga* springing up and establishing itself on savannahs with the introduction of fire-protection; (2) *Dalbergia Sissoo* and *Acacia Catechu* growing up on recently formed shingle deposits in the beds of rivers; (3) mangroves taking possession of newly formed mud flats in littoral regions; (4) mulberry appearing through the agency of water, and spreading through the agency of birds, with the introduction of irrigation in the Punjab plains, where the pre-existing vegetation is of a semi-desert character; (5) various species with small light seeds—*Woodfordia*, *Duabanga*, *Wendlandia*, *Trema*, and others—springing up on landslips and other places where the soil has been recently exposed. Among exotic plants introduced by man which have become invasive to a troublesome degree may be mentioned *Lantana aculeata*, *Eupatorium odoratum* in Burma, *Opuntia Dillenii* (prickly pear) in dry regions, *Mimosa pudica* (sensitive plant) on pasture lands, and *Eichhornia Crassipes* (water hyacinth) in creeks and tanks.

'Succession' is the term applied to a series of invasions occurring in the same place. It is generally divisible into three stages: (1) the initial stage, in which certain species of trees, usually with small, light, or winged seeds, take possession of recently formed or newly exposed ground; (2) the transitional stage, in which changes take place on ground already clothed with some sort of vegetative cover; and (3) the climax stage, which represents the farthest advance towards a hygrophilous type of vegetation which the locality is capable of supporting. On this basis tropical evergreen forest, which probably represents the climax vegetation in humid regions, and persists as such as long as external conditions remain unaltered, may be regarded as the highest type of woodland formation, and succession which proceeds from a xerophilous to a more hygrophilous type is termed 'progressive succession'. The reverse process, in which a more highly developed formation, which may be hygrophilous or mesophilous in type, reverts to a simpler or more xerophilous type, is known as 'regressive succession': it is exemplified by the gradual deterioration of forest through fire, grazing, or otherwise, the more sensitive species giving place to the hardier and more xerophytic species. 'Parallel succession' is the term applied to a change from certain types of grassland to parallel types of woodland, and vice versa. This parallelism between certain species of grass and trees respectively has been demonstrated by Hole[1] in the case of the Dun and Siwalik tracts: of xerophytic forms the grass *Saccharum Munja* has its counterpart in the tree *Acacia Catechu*, while of mesophytic forms the grass *Saccharum Narenga* has its counterpart in the tree *Shorea robusta*. In the savannah tracts of the Duars marked parallelism is to be observed between grassland and woodland species. Here on the high-level savannahs whenever the dominant grass is *Saccharum Narenga* the most characteristic tree is *Shorea robusta*. On the moist low-level savannahs these two species are unable to exist; here the dominant grasses are *Saccharum procerum*, *Phragmites Karka*, and others, while among the characteristic trees are *Albizzia procera*, *Bischoffia javanica*, and *Bombax malabaricum*. Grasses are in this respect particularly good soil-indicators, for owing to the perfect adaptation of their light seeds for dissemination far and wide they are among the first plants to spring up in abundance on new ground, and the presence of certain species of grass on such ground will often indicate the tree species which the ground is capable of supporting, and which will almost inevitably make their appearance in due course. Parallel succession is similarly to be observed between certain species of bamboos and trees: in Burma this parallelism is particularly marked between the bamboos *Bambusa polymorpha* and *Cephalostachyum pergracile* on the one hand and the trees *Tectona grandis*, *Xylia dolabriformis*, and their associates on the other, and the conditions which enable these two species of bamboo to thrive may be regarded as equally suitable for the growth of the trees mentioned.

---

[1] *Op. cit.*

Before proceeding to consider some examples of woodland succession it will be of interest to determine what fundamental grounds exist to explain why changes occur in forest formations and associations. So far as India is concerned it may be said at once that there is no evidence to show that any changes in the forest vegetation are attributable to changes in rainfall conditions within recent times. Dr. Walker[1] has produced evidence to show that there has been no radical change in the rainfall of India since 1841, and to lead to the inference—based on records, dating from 1737, of Nile floods arising from rainfall in Abyssinia, to which the Indian rainfall has a strong affinity—that there has been no radical change in the Indian rainfall since 1737. This naturally does not include sudden changes in the vegetation which may occur owing to the effects of abnormal drought; in such cases regressive succession might result.

Woodland succession in India, then, must ordinarily be explained on grounds other than climatic, since temperature statistics likewise do not reveal any radical changes. Provided external conditions remain unchanged, a formation may possibly retain its character for an indefinite period. This is probably the case not only with tropical evergreen forest but also with many types of deciduous forest. Nevertheless the equilibrium of a formation is often highly unstable, and the slightest change in external conditions may result in a corresponding change in the vegetation. It is not always sufficiently realized that in the great majority of cases this change takes place through a change in the conditions under which the existing vegetation had its origin, that is, the conditions under which the seed is able to reach the ground and germinate and the seedling is capable of establishing itself have undergone some radical alteration. This being so, whatever may be the external stimulus which leads to a change in the type of forest, the reasons why such a change has been brought about as a result of such a stimulus cannot be determined without a close study of the requirements of the seedlings of the species concerned. Changes in external conditions may be brought about in various ways. Frequently the change takes place by reason of conditions (moisture, shade, &c.) produced by the formation itself: it may also be brought about by river action or other forms of erosion and deposition, by grazing, fire, or the direct action of man. In some types of forest the equilibrium of the existing vegetation is maintained by the action of annual forest fires, and some remarkable cases may be observed of a complete alteration in the type of forest brought about through the introduction of fire-protection in areas previously subjected to regular burning. Succession in such cases is progressive, the succeeding type of forest being more hygrophilous than the pre-existing type. Examples of progressive succession due to the introduction of fire-protection will be found under *Shorea robusta* (vol. i, pp. 71–3), *Tectona grandis* (vol. ii, pp. 724–8), *Macaranga denticulata* (vol. iii, p. 848), and *Cedrus Deodara* (vol. iii, p. 1107). In all these cases it will be found that an alteration in the type of forest has been brought about by a change in the conditions under which seedlings of the pre-existing type are capable of establishing themselves, this change being directly attributable to the introduction of fire-protection. In the case of sal in the Duars continued fire-protection has produced soil conditions unfavourable to the establishment of sal seedlings but favourable to the establishment of various evergreen species with which the sal is unable to compete, and the process to be observed in these conditions is one of gradual succession from sal forest to an evergreen type devoid of sal: in this case unfavourable soil conditions, rather than want of light, appear to be the primary cause of the change of type, since the admission of light has proved to be ineffective in bringing about the establishment of sal seedlings.

---

[1] Gilbert T. Walker, On the Meteorological Evidence for supposed Changes of Climate in India, Mem. Ind. Met. Dept., vol. xxi, pt. i, 1900.

The case of teak in Burma is probably somewhat different, though the factors which prevent the establishment of teak seedlings in the moister types of fire-protected forests have not been so fully studied as in the case of the sal. In many cases fire-protection in the teak forests of Burma has resulted in an excessively dense growth of bamboos, the natural companions of the teak; this suggests parallelism, with soil conditions not unfavourable to the establishment of teak seedlings, in which case the failure of the teak to establish itself is probably due to competition with the bamboos and want of light. In many cases the competitors of the teak, as a result of the introduction of fire-protection, are fast-growing softwoods or evergreen species, which frequently form a dense undergrowth. The factors preventing the establishment of the teak may be various, but among reasons which alone are sufficient to account for it are the failure of teak seed to germinate on ground which is not exposed to the heat of the sun, and the inability of young teak plants to struggle against heavy undergrowth or to survive under dense cover. In moist regions progressive succession, even without the stimulus of fire-protection, is sometimes revealed by the presence of large teak trees standing in dense evergreen forest. From a knowledge of the requirements of teak seedlings the idea that the teak trees originated in that type of forest may be at once dismissed: they must have started life either in the open or in a deciduous type of forest of no great density, and the evergreen forest must have encroached on the ground subsequently, probably under the stimulus of conditions of soil and shade produced by the pre-existing deciduous forest.

Numerous other instances of progressive succession consequent on the introduction of fire-protection might be quoted from almost every part of India. Not the least interesting is that in which *Cedrus Deodara* is succeeding *Pinus longifolia* in certain parts of the western Himalaya where the zones of these two trees adjoin. Another interesting case is that in which burnt savannah lands in the eastern sub-Himalayan tract, on which the characteristic trees are fire-resisting species such as *Shorea robusta*, *Careya arborea*, *Dillenia pentagyna*, and *Bombax malabaricum*, on the introduction of fire-protection become rapidly occupied by quick-growing short-lived species such as *Macaranga denticulata*, *Trema orientalis*. and *Callicarpa arborea* : these are succeeded by mixed deciduous forest, which finally gives place to evergreen forest, though in the moister localities the deciduous stage may be wanting, while in the drier localities the evergreen stage may not be reached.

Progressive succession in riverain areas is well illustrated in the sub-Himalayan tract. New deposits of sand and shingle in the beds of rivers become occupied first by certain grasses in open clumps, of which the most characteristic are *Saccharum Munja*, the sand form of *S. spontaneum*, and *Triraphis madagascariensis*. Tree vegetation in the shape of gregarious crops of *Dalbergia Sissoo* and *Acacia Catechu*, sometimes preceded by *Tamarix dioica*, soon makes its appearance : the seedlings of these species are light-demanding and intolerant of weed-growth, while their growth is specially favoured by a porous soil with sufficient subsoil moisture. and these are the conditions which they encounter in these open clean porous shingle-beds, where subsoil moisture is obtained by percolation. After the crops of *Dalbergia* and *Acacia* establish themselves, an undergrowth of *Adhatoda Vasica* or other shrubs frequently makes its appearance : this, combined with the shade of the overhead trees, produces conditions which render it impossible for the *Dalbergia* and *Acacia* to reproduce on the same ground, for although seedlings of these trees are often found in quantity under the parent trees early in the rainy season, these soon die off. New species, however, make their appearance, and in time the forests change to a mixed deciduous type with such trees as *Bombax malabaricum*, *Odina Wodier*. *Garuga pinnata*, *Holarrhena antidysenterica*, *Ehretia laevis*, and others, with *Acacia Catechu* and *Dalbergia Sissoo* occasionally persisting or even reproducing where the ground is sufficiently open and clean. In course of time with the gradual accumulation of vegetable débris and the action of earthworms and other agencies the upper strata of the alluvium become gradually altered from sand and shingle to loam with a water content sufficient to allow of the establishment of sal seedlings, and the mixed deciduous forest may eventually give place to sal forest. This particular succession is not the invariable rule, but it is distinctly traceable in some localities.

The succession which takes place on the alluvial tracts along the Indus in Sind is of a regressive nature. On recently formed alluvium two species of *Tamarix* are usually the first woody species to make their appearance. These are followed by *Acacia arabica* and *Populus euphratica* on alluvium still subject to river floods, while later, on land elevated above the reach of all but abnormal floods, ***Prosopis** spicigera* appears. Finally, on the highest and driest ground of all, these trees give place to semi-desert species, namely *Capparis aphylla*. ***Salvadora** oleoides*, and *S. persica*. This regressive succession is due to the gradual failure of the water-supply in an arid climate.

No better examples of regressive succession due to the action of man are to be found than in places where shifting cultivation is carried out. In the ***ghat*** forests of Coorg there is every reason to assume that the existence of deciduous forest is due to the practice of shifting cultivation formerly carried out on an extensive scale. The local conditions appear to be the same for evergreen and deciduous forests, but fire is very destructive to the former, and wherever shifting cultivation with the attendant burning is known to have been practised, deciduous forest is now present. In many of the hilly tracts of Burma, Chittagong, and Arakan shifting cultivation has converted tree forest into pure bamboo forest of a parallel type.

These examples of succession will suffice to indicate the great importance of a correct understanding of the causes leading to it in each individual case. In almost every locality changes in the type and composition of the forest crops are to be observed in progress, and the term 'rotation of crops' has been somewhat loosely applied. This term, as applied to forest crops, is scarcely analogous to the term as applied to agricultural crops, where it denotes temporary exhaustion of the soil so far as one crop is concerned and the necessity for growing another form of crop in succession to it. On the other hand, so far as evidence in India goes at present, if no radical alteration in the subsoil has taken place—as in the case of the riverain forests of Sind—there seems to be no reason why ground which at present supports a healthy crop of trees should not continue to support a healthy crop of the same species provided the seedlings are able to establish themselves successfully. But in speculating as to the reason for the failure of a crop to regenerate under itself it is sometimes forgotten that existing conditions for regeneration may be totally different from those which prevailed at the time the crop came into being. In some cases this may be due to altered soil conditions. Normally any changes which have taken place in the soil are confined to the surface layers, which are anastatic, and do not extend to the subsoil, which is eustatic: they therefore affect the roots of seedlings rather than those of the larger trees. Conditions favourable for the establishment of the seedling can often be created artificially by opening or completely removing the canopy and clearing and burning the undergrowth, while if the soil has been brought into an unsatisfactory state of aeration it may be necessary to cultivate field crops for a year or two. In the sal forests of the Duars, in the teak forests of Burma, and in the deodar forests of the western Himalaya such treatment has proved entirely successful in effecting the establishment of reproduction—which may have to be induced artificially—in places where none was capable of establishing itself under the old crop.

Gregariousness is closely connected with conditions of seeding and reproduction as well as with the struggle for existence. Gregariousness due to specially favourable conditions of seeding and germination is to be seen in the case of many species which rapidly take possession of newly exposed ground owing to the production of small, light, or winged seeds. Among trees those with small light seeds, such as *Macaranga*, *Wendlandia*, *Trema*, ***Alnus***, ***Tamarix***, and others, as well as pines and other conifers with winged seeds, owe their gregariousness largely, and in some cases entirely, to conditions favourable for seeding and germination.

As a general rule the more favourable a locality is for vegetation the greater the number of species struggling for existence in it, and here gregariousness is the exception rather than the rule: this is well illustrated in tropical evergreen forest. But even here cases may occur in which some special advantage possessed by one or a few species over the others may enable them to regenerate in masses, and gregariousness may result over areas of greater or less extent. In localities where conditions for plant life are more or less adverse the struggle for existence between species is small or absent, and gregariousness may result through the absence of competition and the capacity of one or a few species to grow under unfavourable conditions. This probably accounts largely for the gregariousness of certain species in dry localities, for instance *Anogeissus pendula*, *Prosopis spicigera*, and *Boswellia serrata*, or at high elevations, for instance *Betula utilis* and *Juniperus* spp. Certain types of soil or geological formation, in producing conditions adverse to most species and thus favouring one or a few species, may cause gregariousness; this accounts in part for the gregariousness of *Dipterocarpus tuberculatus* on laterite, *Pinus longifolia* on quartzite and other dry formations, *Acacia arabica* on black cotton soil, and *Butea frondosa* on badly drained ground. Vegetative reproduction may account in some cases for gregariousness. In arid regions *Prosopis spicigera* may rely entirely on sucker reproduction to maintain its existence, and may become the sole survivor owing to this power. In certain tracts *Aegle Marmelos* forms pure forests on stiff clay, and on this unfavourable ground it probably owes its persistence largely to its power of reproduction from suckers. *Diospyros Melanoxylon* is at times also gregarious owing to its power of reproduction from suckers, while teak sometimes becomes gregarious as the sole survivor in forest subjected to lopping, cutting, and burning, owing to its remarkable power of endurance. Gregariousness is often due to immunity from damage by grazing, which favours certain species at the expense of others. Among species favoured in this way are *Butea frondosa*, *Holarrhena antidysenterica*, *Casearia tomentosa*, *Lagerstroemia parviflora*, *Woodfordia floribunda*, *Gardenia* spp., *Strychnos Nux-vomica*, *Clerodendron infortunatum*, *Adhatoda Vasica*, and many Euphorbiaceae, including *Cleistanthus collinus*, *Mallotus philippinensis*, *Sapium sebiferum*, *S. insigne*, *Jatropha Curcas*, and *J. gossypifolia*. Gregariousness is sometimes characteristic of some peculiar habitat tenanted by only a few species adapted for existence in it, as in the case of mangrove and tidal forests.

In many cases, however, gregariousness may be due to a combination of factors, some of which have been mentioned, the complexity of which may render it difficult to explain the precise cause in each case. The exact reason for gregariousness in the sal is by no means easy to determine. In favourable years seed is produced in vast quantities, its germinative power is high, and the ground is carpeted with young seedlings; these die off in quantity, but nevertheless under conditions which are at all favourable many survive, and once established these have the power of persisting for a considerable time under moderate shade and of recovering from the effects of fire, frost, and other forms of injury. These are at least some of the factors operating to produce the characteristically gregarious sal crops. Among the dipterocarps generally gregariousness is characteristic of the more xerophilous rather than of the more hygrophilous species (see introduction to Dipterocarpaceae).

Gregariousness does not necessarily indicate the most favourable conditions for growth. In some of the dry areas of the Indian Peninsula teak is so plentiful as to be almost gregarious, but it is of small size compared with the teak found scattered in mixture with many other species in the forests of Burma and the Western Ghats. *Hardwickia binata* is more gregarious on trap than on sandstone and granite; yet on the former it is of comparatively small size, while on the latter, though more scattered, it reaches larger dimensions. *Butea frondosa* is sometimes gregarious on badly drained ground, but the growth is poor. *Pinus longifolia* often reaches a large size in mixture with *Quercus incana* on fertile soil, while on the poorest soils in the region of the pine it is often the only species that will exist, though it is stunted on such ground.

Although gregariousness is of special advantage to a species in its struggle against other species, it does not follow that it is the direct outcome of a preference for a social life, as is sometimes imagined. It is nothing more than the effect produced by certain conditions which specially favour a species in its reproduction and subsequent struggle for existence. For this reason a species may be gregarious in one place and not in another. Even the teak in Burma, which is a typically sporadic tree, sometimes springs up gregariously on abandoned temporary cultivation in places where teak seed-bearers are present. This is due largely to the fact that teak seed retains its vitality for years, and an accumulated supply of seed lies dormant in the ground, awaiting favourable conditions for germination. These are secured by the complete clearing of the forest growth and the burning of all refuse prior to cultivation with field crops: after the crops are reaped and the area is abandoned the teak is left in possession of the area, and the young plants establish themselves rapidly owing to the favourable light conditions and to their power of resistance to fire. Regarded purely from the point of view of association, trees which are not normally gregarious can as a rule be grown successfully in pure crops: from a silvicultural point of view, however, there are other factors to consider, among which are liability to disease or insect attacks and soil-protective capacity.

SILVICULTURAL TREATMENT. The ultimate aim of practical silviculture is the correct treatment of tree crops with the view of securing a given object; in most cases the object is to produce the highest permanent money return, involving the fullest utilization of the ground for the production of useful and valuable material. The only true basis of forest management is the detailed silvicultural study of the trees concerned, not only as individuals but also as components of communities. The vast natural forests of India, representing the greatest diversity of types and containing species exhibiting the utmost variation in silvicultural characters, present problems of a most intricate kind, the solution of which is impossible without a close study, in each case, of the oecological factors bearing on invasion, succession, and the struggle for existence. This is the more necessary in a country like India, where natural forests play a predominant part, where succession often occurs with such rapidity as to suggest a state of unstable equilibrium, and where the natural trend of this succession may be diametrically opposed to what is desirable from an economic point of view. In this respect nothing has been more unforeseen than the effect of fire-protection in certain types of forest in moist regions, where its introduction has resulted not in the encouragement of the more valuable species, as was anticipated, but in the stimulation of progressive succession to a more hygrophilous type in which the survival of the species which it was desired to encourage above all others has been rendered impossible.

In the present work the silvicultural characters and requirements of the various species are recorded so far as observations and experiments have yielded any results. It should be noted, however, that information on such matters as light requirements, susceptibility to damage by frost, drought, grazing and other agencies, power of vegetative reproduction, and other characteristics, may be misleading if applied too generally, since information of this kind is to some extent of a comparative nature. Thus a frost-hardy species of the plains of India would succumb to cold at a high altitude, while a species regarded as drought-resistant in some localities might not be able to survive in an arid region. A shade-bearer of the deciduous forests might quickly become suppressed in dense evergreen forest. The temperate Himalayan species, though ordinarily hardy enough in their own habitat, are somewhat tender in the climate of Great Britain. It follows that some limitation is necessary in applying descriptions of silvicultural characters, and in this work such characters are ordinarily taken to apply to the natural habitat and environment of a species.

The scientific treatment, as high forest, of the large areas of irregular and for the most part mixed forests of India and Burma is one of the most difficult problems with which forest management has been faced. A provisional method of treatment, the main object of which is to utilize the available stock of mature and over-mature trees of marketable species, while endeavouring to safeguard the future stock as far as possible, was adopted in the early days of forest administration: it has continued to be the principal method of treatment down to the present day, and it must continue in force for many years to come, particularly in the less accessible tracts. This provisional treatment consists in working over the forests under a definite felling cycle and removing trees which have reached exploitable size, seed-bearers being left where natural reproduction is deficient. On the analogy of the selection system of Europe the fellings in question have been termed selection fellings, though they differ materially from those of the true selection system, under which normality is aimed at. These fellings cannot be regarded as anything but a provisional means of working the forests pending the introduction of more scientific systems of management. Their most serious defects are—first, that they do not tend towards the establishment of the normal forest; second, that they do not ensure adequate reproduction; and third, that in many cases they do not sufficiently take into account the silvicultural requirements of the species, particularly in the case of light-demanders. The constant removal of the more valuable species must inevitably lead to the deterioration of the forest: the felling of inferior species, it is true, is to a certain extent carried out along with the main fellings, but in too many cases it is found impossible to carry out this work to the extent desirable, while at the best it concerns itself with the maintenance of the existing crop rather than with the building up of the future crop by inducing reproduction. Another serious defect of these selection fellings is the diffusion of work entailed by them, rendering the profitable construction of export works in many cases out of the question. There is little doubt that the adherence to these provisional selection fellings is to be explained largely on the ground of lack of sufficient knowledge of the methods necessary to secure reproduction by practicable means over the vast areas to be dealt with, and in this respect it must be admitted that in the case of the great majority of species we are as yet only on the threshold of enlightenment.

Within recent years there has been marked progress in the introduction of rational silvicultural systems in India. The defects of the selection fellings, with all the disadvantages of diffused working, are becoming more fully realized, and attention has of late been directed to the more extensive application of concentrated systems of regeneration in high forest, which until recently have been applied almost solely to pure crops of *Pinus longifolia*. Such systems aim at the complete regeneration of definite areas within given periods of time, and the eventual result will be the production of more or less even-aged, though not necessarily pure, crops in which the proportion of valuable species will be considerably higher than it is in the irregular natural crops as we find them. Some advance has already been made in the introduction of concentrated systems of regeneration in the sal forests of the United Provinces and Bengal and the teak forests of Burma, an account of which will be found under *Shorea robusta* and *Tectona grandis* respectively. The more extensive application of such systems will necessitate the close study of conditions for reproduction, and of the silvicultural characters of the species dealt with, to an extent never deemed necessary under the old system of selection fellings, and this will be not the least satisfactory result of the silvicultural revival now in progress. One striking fact which has already revealed itself is the great diversity of treatment necessary to secure reproduction under different conditions, even in the case of one and the same species, and in the application of the principle of concentrated regeneration Indian forestry will doubtless in time show a remarkable number of variations in matters of detail. The value of fire as an aid to reproduction is becoming more and more apparent, and under many conditions controlled burning will play an important part in regenerative operations, both in broad-leaved and in coniferous forest. In future artificial reproduction will almost certainly be resorted to on a much larger scale than has been the case in the past. In the moister types of sal forest in the Bengal Duars artificial reproduction is now relied on as the sole means of regenerating the sal, a species which until recently has been regarded as pre-eminently adapted for natural reproduction. Under suitable conditions natural reproduction in the teak forests of Burma can be secured with great success by clear-felling followed by thorough burning and weeding, but so far no system of natural reproduction has proved so economical and efficient as artificial reproduction with the aid of shifting cultivation. Artificial reproduction is no less a matter for local study than natural reproduction, since conditions vary to such an extent in different regions that the methods adopted must vary greatly even for one and the same species.

The next few decades should see great developments in the elaboration of scientific systems of forest management in India, leading to more economic working, more complete utilization of timber and other forest produce, the establishment of new forest industries, the extension of existing industries, and increasingly satisfactory financial returns. But in contemplating such progress let it never be forgotten that its success will depend on sound systems of forest management, which in turn must depend on strict attention to correct silvicultural details: future material progress in Indian forest development, therefore, must rest above all on the sure foundation of silvicultural research.

CONCLUSION. This work would have lost much of its value but for the generous assistance which I have received from others. I am particularly indebted to Mr. R. S. Hole, Forest Botanist, and to Mr. E Marsden, my successor as Silviculturist at the Forest Research Institute, Dehra Dun, for much help and advice, while I am specially indebted to Mr. H. Tireman for a number of useful notes and specimens from Coorg. Numerous other forest officers have given me help in various ways, and I gladly acknowledge in particular some useful notes from the Punjab by Messrs. C. G. Trevor and R. N. Parker, notes on Bengal species by Sir Henry Farrington and Messrs. F. Trafford, J. R. P. Gent, H. S. Gibson, and E. A. C. Modder, notes from Assam by Mr. A. R. Dicks, Rai Bahadur U. N. Kanjilal, and Rai Sahib Ramnath Mukerjee, specimens from Burma prepared by Mr. J. D. Clifford with the assistance of Maung Po Thit, notes from the United Provinces by Mr. J. N. Oliphant, notes from Sind by Messrs. H. L. Newman and A. C. Robinson, notes by Mr. R. Bourne, with specimens, from Malabar, notes from Cuddapah by Messrs. T. A. Whitehead and A. Raju Nayakar, and notes from Baluchistan by Lala Mul Raj. For many of the photographic illustrations I am indebted to the kindness of others. Wherever known the photographer's name has been inserted in the list of illustrations at the beginning of each volume, but in a few cases photographs in the collection of the Forest Research Institute have been employed, of which the photographers' names could not be ascertained, and it is hoped that the omission to record them will be pardoned.

During the preparation of this work I have had frequent occasion to consult Brandis's *Indian Trees* and *Forest Flora of North-West and Central India*, Gamble's *Manual of Indian Timbers*, Talbot's *Forest Flora of Bombay*, Haines's *Forest Flora of Chota Nagpur*, Parker's *Forest Flora of the Punjab*, Kanjilal's *Forest Flora of the Siwalik and Jaunsar Forest Divisions*, Bourdillon's *Forest Trees of Travancore*, and, for species grown in the British Isles, Elwes and Henry's *Trees of Great Britain and Ireland*. Frequent reference has also been made to the pages of the *Indian Forester*. Finally I wish to acknowledge gratefully the constant assistance given me by my wife in the laborious work of preparing this book for the press.

ORDER I. DILLENIACEAE

A tropical order, with one genus of some interest in Indian forestry.

DILLENIA, Linn.

Trees with large leaves on which the lateral veins are numerous, prominent, parallel, and nearly straight. After the two described below perhaps the most important are: (1) *D. aurea*, Smith, a small deciduous tree of Oudh, Chota Nagpur, on dry hills in Singhbhum, very common in places on clay schists (Haines), and the drier hill forests of Burma up to 3,000 ft.; (2) *D. pulcherrima*, Kurz, a deciduous tree occurring in *indaing* and low savannah forests in Burma.

Species 1. *D. indica*, Linn.; 2. *D. pentagyna*, Roxb.

1. **Dillenia indica,** Linn. Syn. *D. speciosa*, Thunb. Vern. *Chalta*, Hind., Beng.; *Uva*, Tam., Tel.; *Mota karmal*, Mar.; *Thabyu*, Burm.

An evergreen tree attaining a height of 30–40 ft., or more in favourable localities, with spreading branches and a rounded crown with handsome bright green shady foliage. Bark smooth, red, moderately thick, exfoliating in small hard scales.

DISTRIBUTION AND HABITAT. Moist and evergreen forests of the eastern sub-Himalayan tract, Assam and Burma, and the moister parts of the Indian Peninsula. Often planted for ornament. Characteristically found along the banks of tropical forest streams and other damp places, on deep rich moist soil. In its natural habitat the tree is found in regions with an absolute maximum shade temperature of 95°–105° F., an absolute minimum of 35°–65° F., and a rainfall of 80 to 200 in. or more.

LEAF-SHEDDING, FLOWERING, AND FRUITING. In Dehra Dun the tree is almost leafless for a brief period in July. The large handsome white flowers appear in June and July, or in August at Dehra Dun; the petals quickly fall. The green fruits (Fig. 1, *a*, *b*), resembling large apples, commence to ripen in October, and continue to fall to the ground throughout the following cold and hot seasons. The fruit is a pseudocarp 3–5 in. in diameter, consisting of the much-thickened sepals enclosing a ring of fleshy carpels in which the seeds are embedded in a glutinous mass of pulp. The seeds (Fig. 1, *d*) are compressed, reniform, dark brown, with hairy margins, when dry measuring about 0·25 in. by 0·15 in.; 1,100–1,500 seeds weigh 1 oz.

The fruits are buoyant in water, and those which drop into the streams from the trees along their banks are carried down until stranded. Wild elephants eat the fruits, and are a possible cause of the spread of the seed. Under ordinary conditions, however, the seed has no means of escaping from the fruit owing to the stiff tight covering of thickened sepals, and Nature's method of overcoming the difficulty is interesting. The fruits on reaching the ground quickly turn brown, decay, and in the hot season shrivel into dry masses; at the same time white ants eat out the interior and fill the dry shell with their earth. The seeds, however, remain untouched, and at the commencement of the rains they germinate in the earth of the white ants, and seedlings burst out through all the cracks and joints of the dried shell of the fruit as if growing in a flower-pot (Fig. 1, *c*). The heavy rain soon breaks up the remnants of the fruit and washes away the seedlings, the roots of which obtain a footing wherever they can; many seedlings, however, die before this is accomplished. Where the fruits have become partially buried and the seedlings remain *in situ* they succeed best.

GERMINATION (Fig. 1, *e–g*). Epigeous. In the case of detached seeds the testa, enclosing the cotyledons, is usually carried up, dropping with the expansion of the cotyledons. When, as under natural conditions, germination takes place within the shell of the fruit, the hypocotyl often becomes much curved in its efforts to emerge, and the testa is frequently left inside.

THE SEEDLING (Fig. 1).

Roots: primary root long, tapering, wiry, flexuose: lateral roots numerous, moderately long, fibrous. *Hypocotyl* distinct from root, 1·7–2·5 in. long, terete, fusiform or tapering slightly upwards, glabrous, often much bent and curved during germination. *Cotyledons* sub-sessile or with very short petioles, green, foliaceous, 0·6–0·8 by 0·3–0·4 in., ovate, acute or acuminate, base acute, entire, glabrous. *Stem* erect, more or less covered by the expanded petiole bases. *Leaves* alternate, crowded: petiole 0·1–0·3 in., somewhat enlarged at the base and partly sheathing the stem: lamina 0·5–2 by 0·4–0·8 in., elliptical obovate, sharply serrate, glabrous above, pubescent beneath, lateral veins parallel, prominent.

In the second season the seedling develops considerably, the stem thickening and the leaves acquiring more the character of those of the adult plant. At Dehra Dun nursery plants reached a height of 6 to 10 in., 2 to 3½ ft., and 5 to 6 ft. by the end of the second, third, and fourth seasons respectively. Seedlings suffer from drought in dry weather, and require regular watering in the nursery. Where raised in localities subject to frost the seedlings are decidedly tender, and require protection.

SILVICULTURAL CHARACTERS. The tree is a shade-bearer, vigorous saplings being found in the forest under dense shade. It thrives best in damp situations on deep fertile soil. In the abnormal frost of 1905 trees in gardens in the Punjab and United Provinces suffered severely. The tree reproduces satisfactorily from coppice-shoots, as in the Holongapar coppice coupes, Assam.

ARTIFICIAL REPRODUCTION. Many attempts have been made at Dehra Dun to ascertain the best methods of propagating the tree by seed. Failure resulted in every case where the seed was extracted from green or rotten (not dry) fruits. Two methods proved successful:

(1) To collect the fruits about December to February and dry them thoroughly in the sun for a few months, then to hammer them open and extract the seeds by winnowing; then to sow the seeds about May in boxes or nursery beds and water them regularly.

(2) To place the fruits on the ground and leave them till the commencement of the rains, when the seeds germinate inside as already described; the seedlings obtained thereby are then removed and planted in nursery beds.

Transplanting can best be done at the commencement of the first rains after sowing, when the plants are one year old; they are then usually 3–4 in.

high. **Even** in the second or third year after sowing the plants can be transplanted without much risk if care be taken to keep earth round the roots.

RATE OF GROWTH. The tree grows moderately fast. Gamble's measurements gave 7 and 9 rings per inch of radius for two specimens, corresponding to a mean annual girth increment of 0·9 in. and 0·7 in.

2. **Dillenia pentagyna**, Roxb. Syn. *D. angusta* and *D. pilosa*, Roxb. Vern. *Aggai*, Oudh; *Kallai*, C.P.; *Aksi*, Duars, Assam: *Karmal*, Mar.; *Kangal*, Kan.; *Nai teku*, Tam.; *Zinbyun*, Burm. (Fig. 2.)

A deciduous tree attaining in favourable localities a height of 60–70 ft. and a girth of over 8 ft., with a rounded crown and very large leaves, those of young saplings and coppice-shoots sometimes as much as 3 ft. in length. Bark greyish brown, moderately thick, smooth, with shallow depressions.

DISTRIBUTION AND HABITAT. Sub-Himalayan tract from Oudh eastwards, Bengal, Chota Nagpur, Assam, Burma, central, western, and southern India. In Oudh the tree occurs mainly in sal forests and does not attain very large dimensions. In Bengal and Assam it is characteristic of savannah lands and is common in sal forest. In Chota Nagpur it is not very common, and is confined mainly to low ground, but according to Haines it ascends to 2,000 ft. on Parasnath. In Burma it is a very common tree in certain types of lower mixed deciduous forest on alluvial ground, where sometimes it becomes almost gregarious: it also extends into the upper mixed forest. Talbot says that it occurs throughout the Bombay Presidency in deciduous monsoon forests, that it is usually found stunted and of medium size in the dry open forests of Guzerat, Khandesh, and other Deccan districts, and also occurs in the mixed forests of North Kanara, where it attains considerable dimensions.

In its natural habitat it is found in regions with an absolute maximum shade temperature of 96°–115° F., an absolute minimum of 32°–60° F., and a normal rainfall of 30–180 in. or more; where the rainfall is less than 45 in., however, the tree is usually stunted.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The leaves turn brown and fall in February, sometimes even in January, and the trees remain leafless for two or three months. The flower-buds appear in January on excrescences along the thick twigs, and even down to fair-sized branches, and the numerous fragrant yellow flowers in fascicles along the leafless branches appear in March–April. The fruits ripen about May–June; they are orange yellow in colour, succulent, edible, about $\frac{1}{2}$–$\frac{3}{4}$ in. in diameter, and fall to the ground soon after ripening. They are greedily eaten by birds. Seeds about 0·2 in. by 0·1 in., rounded or angular, dark brown, smooth, shining; testa hard, but not difficult to break. About 1,300 seeds weigh 1 oz.

SILVICULTURAL CHARACTERS. The tree is a light-demander. It is very sensitive to frost, but stands fire well. Its coppicing power varies, though as a rule it is good: in three plots in coppice coupes 1 and 2 years old in the Tikri forest, Gonda, measured in 1911, *Dillenia* stools had an average of 1·6, 2·4, and 2·6 shoots per stool as against 1·8, 1·7, and 2·2 respectively for sal. Measurements by Mr. C. M. McCrie in 1910 at Ramgarh, Gorakhpur, United Provinces, in coppice coupes 5, 7, and 16 years old, showed an average of 1, 1·75, and 1 shoot per stool as against 1·28, 1·34, and 1·5 respectively for sal. In the Bengal Duars and the plains forests of Burma the tree produces strong stool-shoots in the coppice coupes. On the other hand, Mr. A. E. Osmaston [1] records that of 12 *Dillenia* trees coppiced in a plot in Gorakhpur none produced shoots: these forests suffered severely from drought shortly before the fellings were made, and this may account for the failure.

NATURAL REPRODUCTION. The tree reproduces freely in burnt savannahs, often forming pure patches: the thick almost fleshy shoots of saplings stand burning to a remarkable degree. In the Duars the presence of *Dillenia pentagyna* in sal or mixed forest thus often denotes that the crop has grown up within comparatively recent times out of burnt savannah land.

RATE OF GROWTH. Periodical measurements of *Dillenia* trees in sample plots in sal forest in the Buxa Division, Bengal, showed such slow growth (a mean annual girth increment of 0·25 in.), owing to the fact that the trees were dominated by the sal, that the figures were discarded as unreliable: they are, however, interesting as showing the light-demanding nature of the tree. Gamble's specimens showed 5 to 6 rings per inch of radius, representing a mean annual girth increment of 1·1 in., a fairly rapid rate of growth.

In the Gonda coppice plots referred to above *Dillenia* stool-shoots 1 and 2 years old had average heights of 2·6 ft. and 5·8 ft. respectively as against 4·7 and 8·8 ft. for sal shoots. Measurements in the Gorakhpur coppice plots already mentioned gave the following results in the case of *Dillenia* as compared with sal:

Dillenia pentagyna: rate of growth of coppice, Gorakhpur.

	Mean height.		Mean girth.	
Age.	*Dillenia pentagyna.*	*Shorea robusta.*	*Dillenia pentagyna.*	*Shorea robusta.*
years.	ft.	ft.	in.	in.
2	4·0	3·0	2·0	—
4	7·1	7·0	3·6	2·0
6	9·3	10·3	4·8	2·9
8	11·1	13·0	5·4	3·8
10	12·3	15·3	5·8	4·8
12	13·3	17·5	6·1	5·8
14	13·8	19·2	6·4	6·7
16	14·1	20·9	6·6	7·5

ORDER II. MAGNOLIACEAE

This order, which has most of its representatives in the moist forests of the eastern Himalaya and Assam, contains several trees of great beauty and some of large size.

MICHELIA, Linn.

Large evergreen or deciduous trees of the moist or evergreen forests, chiefly in hilly regions. Besides the two described below, *M. nilagirica*, Zenk., of the evergreen 'sholas' of the Nilgiris, and *M. oblonga*, Wall., a very large tree of Assam, are of some importance in their respective regions.

Species 1. *M. excelsa*, Blume; 2. *M. Champaca*, Linn.

1. **Michelia excelsa**, Blume. Vern. *Bara champ, safed champ*, Nep.

A tall deciduous tree usually with a straight clean bole and a compact or only moderately spreading crown. Bark of young trees whitish, that of old trees light ashy grey with numerous small pits. Mature trees attain a height of 100–120 ft., while sound trees up to 10 ft. in girth are not infrequently found: trees of larger girth are usually unsound. A tree 22 ft. in girth has been reported by Mr. J. R. P. Gent in the Singalila range, Darjeeling. Fig. 3 shows a large tree with its branches characteristically festooned with moss. This is one of the most important timber trees of the Darjeeling hills, where the wood is in great demand for building and other purposes. It furnishes a poor fuel.

---

[1] Ind. Forester, xxxvii (1911), p. 429.

DISTRIBUTION AND HABITAT. Eastern Himalaya at 5,000–8,000 ft., Khasi and Naga hills. In the Darjeeling forests it occurs mixed with oaks (*Quercus lamellosa*, *Q. lineata*, and *Q. pachyphylla*), *Castanopsis Hystrix*, *Bucklandia populnea*, maples, laurels, and other trees. It grows on well-drained hill-sides or ridges, preferring the lighter moist deep loamy soils; it also grows fairly well when planted on moderately clayey soil, but bad drainage and excessive soil moisture are injurious, retarding the development of the tree and producing a stunted growth. Fig. 4 shows a pole crop normally developed, and Fig. 5 a pole crop somewhat stunted owing to an excess of moisture in the soil.

In the natural habitat of the tree the climate is temperate and very wet. The absolute maximum shade temperature varies from 80° to 90° F., the absolute minimum from 20° to 30° F., and the normal rainfall from 90 to 200 in. or more.

FLOWERING AND FRUITING. The majority of the trees flower in March, but sometimes trees may be found flowering in December and occasionally at other times of the year: the flowers are large and white. The seed ripens towards the end of October and in November, and is distributed to some extent by the agency of birds, though much of it germinates where it falls. The seeds, which are covered with a red arillus, are oily and quickly lose their germinative power: about 160 to 210 weigh 1 oz. They are readily devoured by birds and by squirrels, rats, and other vermin. Records of seed-years for some time past show that in 11 years there are on an average 5 good, 3 moderate, and 3 bad seed-years. Hailstorms, which occur mainly in March and April, destroy the flowers or the young fruits before they set, sometimes causing complete failure to produce seed in an otherwise promising seed-year.

SILVICULTURAL CHARACTERS. The tree is a light-demander. Although seedlings grow fairly well under a moderate though high canopy, saplings and poles grown with complete overhead light are more vigorous than those grown under shade. Sudden isolation, as when standards are left in coppice coupes, is apt to cause drying of the crown and the production of numerous epicormic branches: this is probably the result, in part at least, of the altered conditions of soil moisture consequent on the exposure of the ground. The tree coppices well up to a fair size: it does not produce root-suckers. Drought does not ordinarily occur in its natural region, but young plants on southerly aspects are sometimes found to suffer from want of moisture. The tree is frost-hardy. It suffers much if exposed to fire, trees being often killed outright where fires are severe: young trees, however, frequently send up new shoots from the base. It is more subject to the attacks of animals than almost any other tree of its region. Squirrels and tree shrews gnaw the bark near the ground and eat the tips of young shoots: young plants in particular are subject to the attacks of squirrels. The bark is also eaten by cattle and deer, while the tree is a favourite one for deer to rub their antlers on. The leaves and young plants are readily eaten by cattle, horses, and deer, and in grazed areas it is impossible for the seedlings to establish themselves.

NATURAL REPRODUCTION. Good seed years produce an abundant crop of seed, and seedlings of the first year are usually plentiful in the vicinity of seed-bearers. Their further development depends largely on the admission of sufficient light and on their being kept free from suppression by weeds and from damage by fire and grazing. Natural reproduction is found most plentifully on ridges and spurs, the reason probably being that on such places there is more light, less accumulation of fallen leaves, and a less abundant growth of weeds than elsewhere. In the Darjeeling forests natural reproduction is induced by opening the canopy in the vicinity of seed-bearers: wounding the soil has also given success.

ARTIFICIAL REPRODUCTION. In the Darjeeling hills artificial reproduction is carried out to a considerable extent by means of transplanting nursery-raised seedlings. The fruits are collected early in November, and spread out in the sun until the seeds separate from the husks, this taking from a week to a month according to the weather. The seed is then sown within a week, having been kept spread out meanwhile in an airy place under light shade. In the nursery it is sown either in drills or broadcast, the latter method being considered preferable owing to the danger of moles, which find the seed in lines and following up a line devour every seed. When 1 to 2 in. high the seedlings are pricked out 6 in. apart in nursery beds during the first rainy season, but this is sometimes dispensed with.

The seedlings are transplanted to the forest when 3 or 4 years old and 2 to 3 ft. high, the latter size being considered preferable in order to give the plants a better start over the weed-growth. Transplanting is usually carried out in the rainy season, about July, but if the winter rains are favourable it can be carried out successfully in January, especially on northerly slopes. As a rule a spacing of 10 ft. by 10 ft. is considered sufficient; inferior species spring up in the intervening spaces, producing a full crop, and are afterwards cut out, leaving a pure crop of *Michelia*. Careful fencing against deer is necessary. In the Darjeeling hills it is customary to fence every plant until it is out of reach of deer by driving a circle of split stakes round it. For three years cleaning is necessary twice a year, during and towards the end of the rainy season, in order to prevent suppression of the young plants by weeds.

RATE OF GROWTH. According to Gamble the rate of growth is variable, young trees often showing only 4 to 7 rings per inch of radius, older ones 12 to 16; this gives a mean annual girth increment of 0·39 to 0·52 in. A specimen in the Darjeeling Forest Museum, with a girth of 7 ft. 7 in., showed 7 rings per inch of mean radial growth, giving a mean annual girth increment of 0·9 in. Ring countings by Mr. F. G. Henvey, recorded in the Darjeeling working plan, showed 8 to 12 rings per inch of radius, giving a mean annual girth increment of 0·52 in. to 0·78 in. More recent results of ring countings have shown an average of 9 rings per inch of radius, giving a mean annual

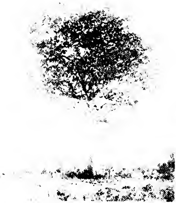

FIG. 2. *Dillenia pentagyna*, girth 8 ft. 6 in., Buxa district, Bengal.

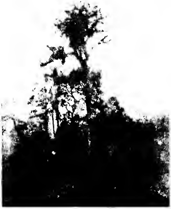

FIG. 3. *Michelia excelsa*, girth 9 ft. 3 in., height about 110 ft., clear bole about 75 ft. Darjeeling Hills.

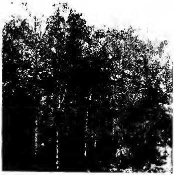

FIG. 4. *Michelia excelsa* pole crop about 20 years old, normally developed. Darjeeling Hills.

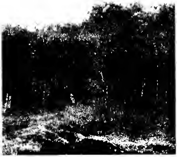

FIG. 5. *Michelia excelsa* pole crop about 20 years old, stunted owing to excess of moisture in the soil. Darjeeling Hills; trees in flower.

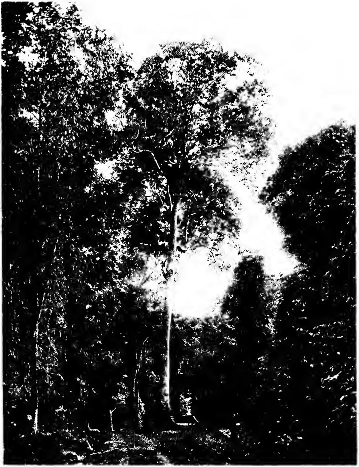

FIG. 6. *Michelia Champaca* in evergreen forest, Bengal Duars; girth 8 ft. 9 in., height 110 ft.

girth increment of 0·7 in., which may be taken as an approximate general **average**.

Mr. H. S. Gibson has furnished the following figures showing the average **height** of seedlings and saplings in the Kurseong forests:

Michelia excelsa : growth of seedlings and saplings, Kurseong forests.

Age.	Height.				Girth.			
	Natural.		Artificial.		Natural.		Artificial.	
Years.	ft.	in.	ft.	in.	ft.	in.	ft.	in.
1	0	7	0	9				
2	1	0	1	6				
3	2	0	2	6				
4	3	0	3	0				
5	5	0	3	6				
6	7	6	4	6				
7	10	0	5	6				
10	14	0	8	0				
15	22	0	14	0				
20	30	0	22	0	1	6	0	10
25			35	0			1	6

A plot of young trees in an abandoned nursery at Rangirum in the Darjeeling hills, measured in 1917, had a mean girth of 9·2 in. and a mean height of 27 ft.; it had 1,376 stems per acre and a volume of 687 cubic ft.

The average rate of growth of coppice-shoots is from 2 to 3 ft. annually.

2. **Michelia Champaca**, Linn. Syn. *M. aurantiaca*, Wall. Champak. Vern. *Champ, champa*, Hind.; *Tita sopa*, Ass.; *Sampighi*, Kan.; *Champakam*, Tel.; *Shembuga*, Tam.; *Saga*, Burm.

A tall handsome evergreen tree with a long clean cylindrical bole, attaining a height of 110 ft. or more and under ordinary forest conditions a girth of 8–12 ft. or more. Bark light grey, smooth, about ½ in. thick. In the Borojhar forest, Buxa Duars, I measured a tree 16 ft. in girth, while Beddome records a tree on the Balarangam hills in Mysore with a girth of over 50 ft.

Distribution and habitat. Wild in the eastern sub-Himalayan tract and lower hills up to 3,000 ft., Assam, Burma, Western Ghats, southern India. Rare in deep valleys cooled by perennial springs, in the Tholokabad and Karampoda forests, Chota Nagpur (Haines). Much cultivated in various parts of India and Burma, especially round temples, for the sake of its fragrant flowers, which are used in religious ceremonies. It is characteristic of moist and evergreen forests, where its tall clean light grey bole stands out conspicuously (see Fig. 6). In the Bengal Duars it is fairly common in the moister and almost evergreen types of sal forest on rich soil. Some fine specimens occur along the foot-hills of this tract. It extends into the Abor country at the lower elevations, and Mr. A. J. Milroy[1] remarks on the large size of the trees he saw there, the best of which measured 10 ft. in girth with a clean cylindrical bole of about 70 ft.: he was informed that the tree grows to still finer proportions in the Mishmi and Khamti countries.

In its natural habitat the tree is ordinarily found in regions where the absolute maximum shade temperature varies from 95° to 105° F., the absolute minimum from 38° to 62° F., and the normal rainfall from 90 to 200 in. or more.

---

[1] Report on the Forest Resources of the Abor Country, 1912.

Flowering and fruiting. The scented yellow flowers **appear in the hot** season and the rainy season, and the fruit ripens about **August or later. The** seeds are dark brown and angular, and **are covered with a pink fleshy arillus**: about 160 to 300 seeds weigh 1 oz. They are oily and **quickly lose their germinative** power. Seed-year records from the Kurseong **and Tista divisions**, Bengal, show that a good seeding may be expected nearly **every year**.

Silvicultural characters. The tree is a moderate **light-demander**. It thrives best in a damp climate, and requires a moist **deep soil**.

Artificial reproduction. The seeds should be sown as **soon after** collection as possible: the seedlings may be **transplanted from the nursery** in the second year after sowing.

Rate of growth. Gamble's specimens showed 6 to 7 rings per inch of radius, giving a mean annual girth increment of about 1 in., which is a fair rate of growth.

ORDER III. ANONACEAE

From a forest point of view this order is not of great importance.

Genera 1. Miliusa, Lesch.; 2. Saccopetalum, Bennett; 3. Canangium, Baill.; 4. Polyalthia, Blume.

1. MILIUSA, Leschenault.

Miliusa velutina, Hook. f. and Th. Syn. *Uvaria villosa*, Roxb. Vern. *Dom-sál*, Hind.; *Barhi, kári*, Oudh, C. P.; *Omé*, Singhbhum; *Thabut-gyi*, Burm.

A moderate-sized, in Burma a fairly large, deciduous tree with a somewhat short trunk, spreading branches, a comparatively large crown, and large soft leaves with an aromatic smell when crushed. Bark dark grey, longitudinally fissured.

Distribution and habitat. Sub-Himalayan tract from the Jumna eastwards, Oudh, Chota Nagpur, Orissa, Central Provinces, Northern Circars, and Burma. In Burma it is found scattered in mixed deciduous forests over a considerable portion of the province, being commoner in the lower mixed than in the upper mixed types. In India it is a characteristic tree in many sal forests, and is also found in open mixed deciduous forests. In its natural habitat the absolute maximum shade temperature varies from 105° to 115° F., the absolute minimum from 30° to 55° F., and the normal rainfall from 40 to 90 in.

Leaf-shedding, flowering, and fruiting. The tree is leafless about February–March, the new leaves appearing in March–May, and the pale yellow flowers with them; the fruit ripens in June–July.

Silvicultural characters. In sal forests the utility of the tree lies chiefly in its capacity for regenerating in small blanks containing coarse grasses, where it forms a natural nurse for the regeneration of the sal. Although somewhat frost-tender, it is conspicuously hardy against drought, as was proved in the abnormal drought of 1907–8 which devastated the sal forests of Oudh: for this reason it has been of special value as an accessory species in these forests. The tree is a moderate shade-bearer. It coppices well, and also reproduces from root-suckers. Mr. A. E. Osmaston records that in coppice experiments in Gorakhpur, United Provinces, of 22 trees coppiced every one sent up stool-shoots. Countings which I made in 1911 in the Tikri forest, Gonda, United Provinces, showed an average of 2·1 shoots per stool for 21 stools in one-year-old coppice as against 2·2 shoots for sal, and 1·4 shoots per stool for 12 stools in two-years-old coppice as against 1·7 shoots for sal. In the Ramgarh coppice coupes, Gorakhpur, in 1910 Mr. C. M. McCrie found in coupes 3, 5, 11, 15, and 16 years old 2, 1·33, 1, 1·16, and 1·15 shoots per stool respectively.

Rate of growth. Figures in existing sample plots show a comparatively slow rate of growth in girth; trees between 1½ and 3 ft. in girth in sample plots in the Lansdowne and Gonda divisions of the United Provinces showed mean annual girth increments of 0·19 in. and 0·15 in. respectively. The rate of growth of coppice-shoots is slower than in the case of sal. In the Gorakhpur experiments referred to above the average height of stool-shoots of one rainy season's growth was 2·1 ft. as against 4·5 ft. for sal. In the Gonda coppice coupes already mentioned coppice-shoots one year old had an average and maximum height of 5 and 8 ft. respectively as against 4·7 and 11 ft. for sal, while in two-years-old coupes *Miliusa* shoots had an average height of 6·5 ft. as against 8·6 ft. for sal. Measurements made by Mr. C. M. McCrie in 1910 in coppice coupes of various ages in the Ramgarh forest, Gorakhpur, showed the following rate of growth of coppice-shoots of *Miliusa* as compared with sal:

Miliusa velutina: rate of growth of coppice, Gorakhpur.

Age.	Mean height.		Mean girth.	
	Miliusa velutina.	*Shorea robusta.*	*Miliusa velutina.*	*Shorea robusta.*
Years.	ft.	ft.	in.	in.
2	5·4	3·0	1·2	–
4	8·2	7·0	1·9	2·0
6	10·0	10·3	2·6	2·9
8	11·6	13·0	3·3	3·8
10	13·1	15·3	3·6	4·8
12	13·9	17·5	4·0	5·8
14	14·6	19·2	4·3	6·7
16	15·1	20·9	4·5	7·5

2. SACCOPETALUM, Bennett.

Saccopetalum tomentosum, Hook. f. and Th. Vern. *Kari. um, umbi,* Hind.; *Gonda,* Uriya; *Chilkadudu,* Tel.

A moderate-sized to large deciduous tree of the Nepal *tarai*, Oudh, Chota Nagpur, and the Indian Peninsula. It is of little economic importance, but is fairly widely distributed, and in Oudh is one of the companions of the sal. It coppices well, the rate of growth of the shoots being somewhat less than that of sal coppice: Mr. A. E. Osmaston records that of 7 trees coppiced in experimental coupes in Gorakhpur, 6 produced shoots with an average height of 3·3 ft. in one rainy season as compared with 4·5 ft. for sal.

3. CANANGIUM, Baillon.

Canangium odoratum, Baill. Syn. *Cananga odorata*, Hook. f. and Th. Vern. *Kadatngan*, Burm.

A very large fast-growing evergreen tree, wild in Tenasserim and often cultivated in different localities for its scented flowers. It may attain a height of 120 ft. or more and has a long clear bole sometimes nearly 100 ft. high. The tree flourishes in damp localities. The seeds are small, 500–600 weighing 1 oz.

4. POLYALTHIA, Blume.

Species 1. *P. cerasoides*, Benth. and Hook. f.; 2. *P. **longifolia***, **Benth.** and Hook. f.; 3. *P. fragrans*, Benth. and Hook. f.

1. **Polyalthia cerasoides**, Benth. and Hook. f. Vern. ***Guthi***, **Tel.**; ***Thabut-thein***, Burm.

A small to moderate-sized tree of Bihar, Chota Nagpur, in valley forests and along ravines (Haines), the Indian Peninsula, usually on dry hills but sometimes in evergreen forest, and Burma, often in *indaing* forest. Mr. J. Donald notes that there is a high percentage of regeneration of this tree as a result of fire-protection in parts of South Chanda. The tree possesses the power of reproduction by root-suckers.

2. **Polyalthia longifolia**, Benth. and Hook. f. Vern. *Asok*, Hind.

A handsome evergreen tree with a round close crown, indigenous in Ceylon and much cultivated in gardens and avenues in India and Burma. Its growth is slow. The seeds, which ripen in July and August, do not keep their germinative power long, and require to be sown as soon as possible after ripening. The young plants do not stand transplanting well, and to ensure the best results the seed should be sown at site or in baskets.

3. **Polyalthia fragrans**, Benth. and Hook. f.

'A tall, evergreen, buttressed tree, 80 ft. high by 2 ft. in diameter, with smooth grey bark. . . . Endemic in the Western Ghats, evergreen tropical rain-forests of the Konkan and North Kanara, often gregarious' (Talbot). The timber is of little value.

ORDER IV. CAPPARIDACEAE

The chief silvicultural importance of this order lies in the fact that some of its members, particularly species of *Capparis* and *Cadaba*, occur in dry or arid tracts where vegetation of any kind is scanty.

Genera 1. CRATAEVA, Linn.; 2. CAPPARIS, Linn.

1. CRATAEVA, Linn.

Crataeva religiosa, Forst. Syn. *C. Nurvala*, Ham.; *C. Roxburghii*, R. Br. Vern. *Bárna*, *biliana*, Hind.; *Nirvala*, Mar.; *Maralingam*, Tam.; *Bitusi*, Kan.; *Kadat*, *kadet*, Burm.

A moderate-sized deciduous tree with long-petioled trifoliate leaves; bark grey, somewhat smooth, with horizontal wrinkles. The soft whitish even-grained wood is used for drums, writing-boards, &c., and in turnery.

DISTRIBUTION AND HABITAT. Throughout most parts of India and Burma, wild or cultivated. It is often found along streams, but sometimes occurs almost gregariously on dry deep boulder formations in the sub-Himalayan tract, for example near Ramnagar.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The tree is leafless in the cold season, the new leaves appearing in February and March. The handsome lax-clustered flowers, white turning yellowish or pale pink, having numerous prominent stamens with purple filaments, appear in March–May (December–April in southern India ?), and the fruit, a hard-rinded many-seeded berry, 1–2 in. in diameter, ripens in the rains (about August in northern India). The seeds (Fig. 7, *a*) are about 0·2 in. in diameter, somewhat compressed, helicoid-reniform or irregularly circular, dark brown ; testa hard but splitting readily along a suture round the seed. About 600–700 seeds weigh 1 oz. Tests at Dehra Dun showed that the fertility of the seed is not high, and that germinative power is retained to some extent for at least ten months.

GERMINATION (Fig. 7, *b–e*). Epigeous. The testa splits, enabling the radicle to emerge. The hypocotyl elongates by arching, and in straightening elevates the cotyledons above ground. The testa clings for some time to the ends of the cotyledons, falling to the ground as they expand.

THE SEEDLING (Fig. 7).

Roots : primary root very long, often becoming 15 in. or more in length in the first season, moderately thick, terete, flexuose : lateral roots fibrous, somewhat fine. *Hypocotyl* distinct from root, 0·8–2 in. long, terete, fusiform or tapering upwards, white at first, soon turning green, glabrous. *Cotyledons* sub-sessile or with petioles 0·1 in. or less, flattened above : lamina 0·6–1·1 in. by 0·1–0·2 in., foliaceous, somewhat fleshy, ligulate, apex and base acute or rounded, entire, green, glabrous, persisting for the greater part of the first growing season. *Stem* erect, terete, glabrous, grey with young parts green ; internodes 0·2–0·4 in. long. *Leaves*, first pair usually opposite, subsequent leaves alternate, normally trifoliate but in first pair leaflets often connate, early leaves small, later ones increasing in size. Stipules absent. Petiole 0·4–1·8 in. long, glabrous, channelled above. Leaflets on short petiolules, entire, glabrous, sub-coriaceous, central leaflet 0·6–4·2 in. by 0·4–1·8 in., ovate or obovate lanceolate, acuminate, lateral leaflets 0·5–3 in by 0·3–1·5 in., obliquely ovate, acuminate or acute.

SILVICULTURAL CHARACTERS. Although often found in moist shady places the tree is more a light-demander than a shade-bearer. It is partial to loose deep alluvial soil near streams, while its long taproot enables it to grow on deep boulder formations where water is at some depth. It is sensitive to frost, at all events in its early stages. It produces root-suckers freely.

NATURAL REPRODUCTION. Experiments carried out at Dehra Dun showed that two conditions favourable for natural reproduction are bare ground and sufficient moisture. Seed scattered in grass or among weeds both on moist and on dry ground, or in dry situations on bare soil, persistently failed to germinate, while if scattered on moist bare ground it germinated both in the open and under dense shade, though in the latter case the shade soon killed off the seedlings.

ARTIFICIAL REPRODUCTION. Seed should be sown at the time of ripening, in the rains, on deep loose soil kept sufficiently watered, or in deep pots or boxes, and transplanted during the following rains. The seed may not germinate, even if kept regularly watered, until about May or June of the year after sowing, in which case the plants will be ready for transplanting about August or early September ; they are then ordinarily about 3–6 in. high. Owing to the long taproot care is necessary in transplanting.

2. CAPPARIS, Linn.

Capparis aphylla, Roth. Vern. *Karil*, Punjab.

A much-branched shrub or small tree of the open dry scrub forests in the Punjab, Sind, Rajputana, Baluchistan, Guzerat, and the drier parts of the Peninsula. In these dry tracts it is associated with ***Prosopis spicigera, Acacia*** *leucophloea*, *Salvadora oleoides*, and other semi-desert species. With ***Prosopis*** and *Salvadora* it forms the bulk of the vegetation of the dry ***rakhs*** of the Punjab plains. Talbot says it is common on alluvium along the banks of the Deccan rivers mixed with *Acacia arabica* and *Zizyphus Jujuba*. It coppices well and produces root-suckers freely. It has a mass of slender thorny green leafless branches, the small caducous leaves being found only on the young shoots. The new shoots appear in the cold season. The tree is a conspicuous sight when covered with red flowers in the early part of the hot weather, about March and April. The round pink fleshy fruit is eaten by birds.

ORDER V. BIXACEAE

This order is not of great silvicultural importance; it contains, however, one tree, *Taraktogenos Kurzii*, King, likely to become of considerable value owing to the oil yielded by its seeds, which is used in the treatment of leprosy.

Genera 1. COCHLOSPERMUM, Kunth; 2. FLACOURTIA, Commers.; 3. HYDNOCARPUS, Gaertner; 4. TARAKTOGENOS, Hassk.

1. COCHLOSPERMUM, Kunth.

Cochlospermum Gossypium, DC. Syn. *Bombax Gossypium*, Roxb. Vern. *Kumbi, gabdi, gejra*, Hind.; *Ganglay, galgal*, Mar.; *Gungu, kong*, Tel.; *Kongillam*, Tam.; *Buruga*, Kan.

A small deciduous tree with palmately lobed leaves and fibrous deeply furrowed bark, occurring in the western sub-Himalayan tract from the Sutlej eastwards, ascending to 3,000 ft., Chota Nagpur, Bundelkhand, the drier parts of the Indian Peninsula, and the dry region of Burma. The tree is characteristic of dry hilly country, occupying the hottest and stoniest slopes. Talbot says it is one of the few species capable of resisting successfully the fierce annual forest fires of the Khandesh Deccan Satpuras. In the abnormal drought of 1899 and 1900 in the Deccan it was only slightly affected. It is a light-demander, coming up in open forests exposed to full sunlight. The tree is leafless from about November or December to May, and the large bright yellow flowers appear at the ends of the leafless branches in February and March; it is then a conspicuous sight. The fruit, a large capsule, ripens in May and June, the seeds being carried long distances by the strong winds which are often prevalent before or at the commencement of the rains.

2. FLACOURTIA, Commers.

Flacourtia Ramontchi, L'Hérit. Syn. *F. sapida*, Roxb. Vern. *Katái, bilangra, kukai, kanju, kakein*, Hind.; *Paker, kaker*, Mar.; *Hunmunki*, Kan.; *Nayuwè*, Burm.

A small rather variable deciduous tree, usually thorny, with thin grey bark.

Distribution and habitat. Common throughout the greater part of India: in Burma it occurs in *indaing* and in dry forest. It is found in the lower scrub forests of the Rawalpindi hills associated with *Acacia modesta* and other dry zone species, thence eastward throughout the sub-Himalayan tract, both in sal forests and in the dry miscellaneous forests of the Himalayan valleys and outer hills up to 4,000 ft. Common throughout Chota Nagpur and the Indian Peninsula in mixed deciduous or scrub forests. In its natural habitat the absolute maximum shade temperature varies from 105° to 118° F., the absolute minimum from 25° to 50° F., and the normal rainfall from 30 to 85 in.

Leaf-shedding, flowering, and fruiting. The tree is leafless usually just before or at the time of flowering, which occurs from December to March. The fruit, which ripens from March to July, is an edible berry, and the seed is spread by birds, which no doubt accounts in part for the wide distribution of the tree.

Silvicultural characters and rate of growth. The tree is somewhat frost-tender and is also readily browsed. It coppices fairly well, measurements made in the Gorakhpur division, United Provinces, showing the following production and rate of growth of stool-shoots as compared with sal in the same coupes:

		5 years old.	9 years old.
Average number of shoots per stool	*Flacourtia*	2·66	1
	Sal	1·28	1·35
Average height of coppice-shoots	*Flacourtia*	8 ft. 1 in.	9 ft. 0 in.
	Sal	9 ft. 2 in.	5 ft. 7 in.

Girth measurements in sample plots in the Lansdowne division, United Provinces, showed mean annual girth increments of 0·2 and 0·31 in., which indicates a slow rate of growth.

3. HYDNOCARPUS, Gaertner.

Hydnocarpus Wightiana, Blume. Syn. *H. inebrians*, Wall. Vern. *Kastel*, *kantel*, Mar.; *Toratti*, Kan.; *Maravetti*, Tam.

A large evergreen tree with brown, somewhat rough bark, and handsome shady foliage.

Distribution and habitat. Common in tropical forests along the Western Ghats from the Konkan southwards and below the *ghats* in Malabar and Kanara in moist situations, especially near water. Very common in Travancore up to 2,000 ft. Often planted. In its natural habitat the absolute maximum shade temperature varies from 94° to 99° F., the absolute minimum is about 60°, and the normal rainfall varies from 90 to 180 in. or more.

Flowering and fruiting. The tree flowers in February–March and the fruit, a large hard-rinded berry, ripens in May and June. The seeds (Fig. 8, *a*), which are 0·8–1 in. long, obtusely angular, are oily and do not retain their germinative power for long; they germinate during the rains shortly after reaching the ground. About 25 to 30 seeds weigh 1 oz.

Germination (Fig. 8, *b*-*f*). Epigeous. The horny testa cracks with the swelling of the seed, exposing the soft whitish albumen, which encloses the

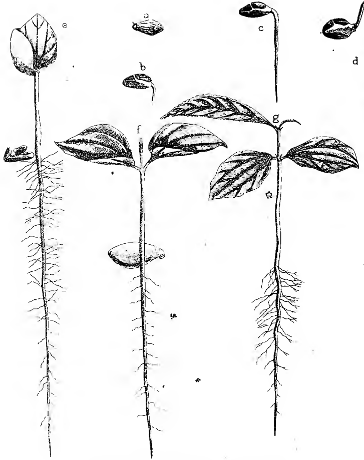

FIG. 8. *Hydnocarpus Wightiana.* Seedling × ½.
a, seed. *b*-*f*, germination stages. *g*, seedling in first season.

cotyledons as in a bag until a taproot some inches long has been developed. **The testa** is usually left underground, while the albumen is carried up and **dropped** when the cotyledons expand.

The Seedling (Fig. 8).

Roots: primary root long, moderately thick, woody, flexuose: lateral roots numerous, fibrous, distributed down main root. *Hypocotyl* distinct from root, 2·8–3·5 in. long, thick, terete, tapering upwards, green, glabrous. *Cotyledons* petiolate: petiole 0·25–0·3 in. long, channelled above, minutely pubescent: lamina 2–2·5 in. by 1·5–2·3 in., cordate or ovate, acute, entire, glabrous or minutely pubescent, palmately 5-veined. *Stem* erect, minutely pubescent; early internodes 0·8–1·5 in. *Leaves* alternate, simple, petiolate. Stipules 0·1 in. long, triangular acuminate, pubescent. Petiole 0·2–0·3 in. long, channelled above, pubescent. Lamina 3–4 in. by 1–1·5 in. elliptical lanceolate, acute, base tapering, sharply serrate, glabrous or with minute hairs on main veins on under-surface; venation arcuate, lateral veins 6–8 pairs in earlier leaves.

4. TARAKTOGENOS, Hassk.

Taraktogenos Kurzii, King. Vern. *Kalaw*, Burm.

A moderate-sized evergreen tree common in some of the tropical forests of Burma and also found in Assam. The seeds furnish the 'chaulmugra' oil used in the treatment of leprosy: this tree, though of economic importance, has not yet been studied silviculturally. In Assam it is reported not to seed well every year. The seeds are very oily, and soon lose their germinative power.

ORDER VI. TAMARICACEAE

TAMARIX, Linn.

Shrubs or small trees known as tamarisks, with small scale-like leaves. Some are interesting from their habit of springing up gregariously on newly formed alluvial land along rivers and by the sea-coast; certain species, notably *T. dioica*, have a remarkable capacity for growing on saline soil, while several are characteristic of dry or arid regions where vegetation of any kind is scanty. The tamarisks exhibit xerophytic adaptations in the scale-like form of their leaves and in some cases in the shedding of the smaller twigs, as in *T. articulata*.

Mr. Hole, who is revising the Indian species of *Tamarix*, informs me that he has determined no fewer than ten species in Baluchistan alone. The commonest species of Sind and north-western India generally, hitherto known as *T. gallica*, he has found to be a new species which he has named *T. Troupii*;[1] this species extends into Baluchistan, where it appears to be common. The true *T. gallica*, Linn., is not at present known to occur in India. *T. indica*, Roxb., is the common species of the Sundarbans and Madras. The largest of the commoner species is *T. articulata*, a moderate-sized tree of the Punjab plains, Sind, and Baluchistan. Perhaps the commonest species in the Indian Peninsula is *T. ericoides*, a handsome shrub with erect broom-like branches and much larger flowers and fruits than the other species, common in the rocky beds of rivers in the Peninsula and extending northwards to Chota Nagpur.

---

[1] Ind. Forester, xlv (1919), p. 247.

Species 1. *T. Troupii*, Hole; 2. *T. dioica*, Roxb.; 3. *T. articulata*, Vahl.

1. **Tamarix Troupii**, Hole. Vern. *Lai, jhau*, Sind; *Jhau*, Hind.; *Pilchi*, Punjab; *Ghazlei*, Baluch.

A glaucous gregarious shrub or small tree with crooked stem, pendulous branches, and light grey smooth bark. The wood, which is not durable, is used for temporary poles and rafters: it is extensively used as fuel, and ranks third among the fuel woods of Sind, where it is employed in locomotives and steamers as well as for domestic use. The brushwood is largely used for protective works along the Indus. The astringent galls are used as a mordant in dyeing.

On saline soil or water-logged ground the growth is bushy and dwarfed, but on better soils this species develops into a fair-sized tree, attaining a maximum height of 30 ft. and a girth of 3 ft., although the average height attained is nearer 20 ft.

DISTRIBUTION AND HABITAT. United Provinces, Punjab, Sind, extending into Baluchistan. Like certain other species of *Tamarix*, this species is able to flourish in regions with scanty rainfall and extremes of temperature. In those parts of Sind where *T. Troupii* and *T. dioica* are common the absolute maximum shade temperature varies from 120° to 125° F., and the absolute minimum from 26° to 40° F., while the normal rainfall varies from under 3 in. to about 13 in. In the case of these two species, however, the water provided by river floods counteracts to some extent the effect of the dry climate. Elsewhere they occur in regions with less marked extremes of temperature and with a rainfall up to 70 in. or more.

The origin of alluvial *Tamarix* forests is typically illustrated along the banks of the Indus in Sind, where this species and *T. dioica* form extensive forests. The newest so-called *kacha* alluvium thrown up by the river and submerged by the annual floods for several feet each year, until raised above the surface of the water by successive deposits of silt, becomes covered in the first place by multitudes of tamarisk seedlings which, provided the soil is not pure sand, soon establish themselves in a dense crop mixed with *kanh* grass (*Saccharum spontaneum*), the grass being killed out subsequently by the tamarisk. As the land becomes more elevated, but still subject to annual floods, *Populus euphratica* and *Acacia arabica* take possession of the ground. Later on, when the land becomes more elevated, and not subject to any but abnormal floods, *Prosopis spicigera* becomes the prevailing species. As these successive species invade the ground the tamarisk becomes gradually suppressed and killed out, though in places even on the older high land crops of *Prosopis* are found with an undergrowth of tamarisk still struggling against lack of water, and often mixed with the typically semi-desert shrub *Capparis aphylla*. In this way it may persist through all successive stages of alluvial forest growth from the pure bushy tracts of tamarisk on the new *kacha* ground to the high-lying older dry alluvium which has become invaded by *Prosopis*.

In its earlier stages the tamarisk is subjected to periodical flooding. It withstands partial submergence without suffering, but complete and continuous submergence for several days kills it. Hence, until the new alluvium reaches the stage of becoming free from complete submergence for any but short periods of time, the young crop cannot be said to have established itself. In its youth the tamarisk has further to contend against the fierce fires which rage through the *kanh* grass with which it is mixed; this grass, which dries up early in the year, is systematically ignited by graziers in search of fresh young grass, the dangerous fire-season being January till April.

The later development of the plant depends largely on the nature of the soil: on stiff clay or on pure sand it tends to remain stunted, while on good alluvial loam sufficiently retentive of moisture it develops into a small tree: the densest crops and the largest plants are usually found in moist silted depressions in old river channels, provided the soil is not too stiff. In these riverain tracts land which has risen above the level of the annual floods often becomes saline, a white efflorescence on the surface, locally known as *kalar*, indicating deterioration of the soil owing to the lack of surface irrigation. The tamarisk persists for a time on such ground, but does not thrive and gradually dies out. In favourable localities *T. articulata* is sometimes associated with the other two species.

Along the Indus the tamarisk crop is of great importance in sheltering from the effects of frost the tender seedlings of the more valuable *Acacia arabica*, which spring up under its shelter from seed brought in by grazing animals, and which are often killed off if they spring up in the open.

FLOWERING AND FRUITING. The panicled spikes of white or pink flowers, which are usually bisexual, appear from July to November, and the capsules ripen and the small seeds are shed from December to February.

SILVICULTURAL CHARACTERS. This plant is a strong light-demander, and will not tolerate the shade of other species; it is hardy, withstanding ordinary frosts. It coppices vigorously, but does not produce root-suckers. It is easily propagated from cuttings. The stem is readily destroyed by fire, but the plant has good power of recovery from the base. It is not much subject to injury by cattle or browsers.

NATURAL REPRODUCTION. In Sind the light seeds are spread by wind and water, and natural reproduction springs up in great profusion on newly formed alluvium: the seed germinates rapidly, and the seedlings establish themselves quickly.

SILVICULTURAL TREATMENT. In Sind the tamarisk is treated in conjunction with *Acacia arabica*, *Populus euphratica*, and *Prosopis spicigera*. Usually the treatment applied to the tamarisk is that of clear-felling with coppice reproduction, while on the new alluvial land seedling reproduction is relied on. Ordinarily a rotation of fifteen years has been adopted hitherto, this being found sufficient to produce the size of fuel billets required. The rotation, however, has recently been increased to thirty years, the importance of the tamarisk being insufficient to justify its being worked on a different rotation from that adopted for *Acacia arabica*, the principal species in Sind. The tamarisk is clear felled along with the principal species, and regenerates by stool-shoots or, where conditions are favourable, from seed.

RATE OF GROWTH. The rate of growth is rapid. Measurements recorded by Mr. A. C. Robinson in the Jerruck division, Sind, showed that the mean annual girth increment for fifteen years in the case of seedling plants was 1·36 in., so that for a rotation of fifteen years the average girth attained is 1 ft. 8·4 in., corresponding to a diameter of 6½ in. The maximum growth recorded was a diameter of 10·5 in. attained in sixteen years, representing a mean annual girth increment of 2·06 in., which is rapid. Strictly speaking, the tree is mature at this age or even earlier, since the base of the stem tends to become hollow by the time an age of fifteen years is reached.

2. **Tamarix dioica**, Roxb. Vern. *Lai*, *gaz*, *lao*, *jhau*, Sind; *Lal jhau*, Beng.; *Jhau*, Hind.; *Lai*, *pilchi*. Punjab; *Byaung-chedauk*, Burm.

A glaucous gregarious shrub or small tree with pendulous branches and reticulately fissured bark. This plant is very similar to *T. Troupii*, with which it is sometimes associated: it is, however, usually smaller and has greyer foliage and broader flower-spikes.

Distribution and habitat. Throughout northern India up to 2,500 ft. in the outer Himalayan valleys, Sind, the Peninsula of India, Bengal, Assam, Santal Parganas, and in the dry zone of Burma, chiefly on sand-banks and in river-beds. It is common along the Ganges, Hooghly, and other rivers, and forms extensive forests along the Indus in Sind. It is also found along the sea-coast. It is common in the sandy or shingly beds of some of the streams issuing from the hills in the sub-Himalayan tract.

A description of the tamarisk forests along the Indus in Sind has been given under the preceding species. In this tract *T. dioica* usually occupies different ground from *T. Troupii*, for although the two are often found together *T. dioica* is largely confined to the high and saline lands which are seldom, if ever, subject to inundation: it is very commonly found on soils heavily impregnated with salts, and has remarkable capacity for existence on such ground.

Flowering and fruiting. The panicled spikes of dioecious pink flowers appear from May to August, and the small capsules ripen in the cold season.

Silvicultural characters. The silvicultural characters of this plant are similar to those of *T. Troupii*, except that it has greater capacity for growing on saline soil.

Rate of growth. The rate of growth is rapid. The figures quoted under *T. Troupii* for the Jerruck division, Sind, include this species also. Mr. Minniken's report of 1878 on the Delhi Bela plantation records an average growth of 1·4 rings per inch of radius, equivalent to a mean annual girth increment of 4·48 in., which is extremely rapid.

3. **Tamarix articulata**, Vahl. Syn. *T. orientalis*, Linn. Vern. *Farásh*, Punjab; *Asrelei*, Sind.

A small to moderate-sized tree with feathery foliage, an erect tapering trunk, and rough grey bark, attaining a height of 60 ft. and a girth of 6–7 ft. or more. The foliage is greyer and more glaucous than that of the previous two species, the twigs being often covered with a saline efflorescence. An important tree in arid regions, the wood being used for agricultural implements, turning, and other purposes, as well as for fuel.

Distribution and habitat. The Punjab plains, Sind and Baluchistan, extending westward to Egypt. It thrives in arid regions with extremes of temperature, where the thermometer reaches a shade temperature of 120° F. or more in the hot weather, while in the winter it sinks below freezing-point; the rainfall in parts is as low as 3 in. The tree is common on the Punjab plains from Delhi to Peshawar and Multan, often associated with *Prosopis* *spicigera*, *Salvadora oleoides*, *Capparis aphylla*, and other species characteristic of these dry regions: it is uncommon in Lower Sind. It thrives best on loam, though it is found also on stiff clay and on sand, while it is capable of growing on saline soils provided there is surface irrigation: it cannot tolerate soil heavily impregnated with salts. It grows more vigorously on land subject to occasional inundation than on land which is never flooded: it is, however, not typical of the new *kacha* alluvium on which *T. Troupii* habitually and *T. dioica* more rarely springs up.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The leaves and extremities of the branchlets are shed in part during the cold season, the new shoots and leaves appearing about May. The small flowers, loosely arranged on long slender spikes, appear from May to July, and the small capsules ripen in the cold season. The seeds are minute.

SILVICULTURAL CHARACTERS. This tree is a hardy one, standing extremes of temperature as well as excessive drought. It withstands ordinary frosts, but in the abnormal frost of 1905 in northern India it suffered to some extent. It coppices freely, sending out quantities of shoots, and grows readily from cuttings, but does not produce root-suckers. Inundations do not harm the coppice as in the case of *Prosopis spicigera*: in the Punjab, however, the coppice-shoots suffer from the attacks of a fungus which causes many of them to decay before they reach marketable size. The tree is browsed by camels.

NATURAL REPRODUCTION. As a rule reproduction from seed is fairly good, but it is doubtful if it is ever thoroughly successful except on land liable to occasional inundation or the accumulation of rain-water. Thus in the Punjab plains in tracts where this tree occurs it is found principally on the more low-lying areas, the higher ground being occupied mainly by *Prosopis spicigera* and other species.

ARTIFICIAL REPRODUCTION. Plants may be raised from seed in nursery beds, but special precautions are necessary owing to the small size of the seeds, which should be mixed with fine moist sand, the mixture being spread over the surface of the beds. The latter should be not more than 2 ft. wide, with a trench on either side which is flooded periodically in order to moisten the beds by percolation; the beds should not be watered by hand. The seed should be sown about January, when it ripens, the seedlings being pricked out in the nurseries when 3 or 4 in. high: the stronger plants may be transplanted during the first rains, but as a rule it will be preferable to defer transplanting till the beginning of the following rains.

Propagation by cuttings is easier and more satisfactory: this system is commonly adopted in Sind in cases where afforestation is undertaken along with the raising of *kharif* field crops. Cuttings as thick as the finger and about 16 in. long should be planted slightly out of the vertical to a depth of 12 in. in prepared nursery beds in February or early March, and the beds should be watered regularly: the cuttings will be well rooted and ready to transplant by August of the same year.

SILVICULTURAL TREATMENT. The tamarisk, along with its associates, is commonly worked as coppice, the rotation adopted being twenty to twenty-five years in order to produce fuel billets up to 10 in. or over in diameter.

RATE OF GROWTH. The growth is rapid. Mr. McIntire records the following results of measurements of coppice-shoots in **Multan district**:

Age of coppice. years.	Diameter. in.	Out-turn of material over 2 in. in diameter per stool. cubic ft. stacked.
5	2 to 4	1 to 2
10	4 to 7	3 to 15, av. 8
15	6 to 10	5 to 25, av. 15
20	7 to 12	8 to 40, av. 25

The growth is much faster on low-lying ground subject to inundation than elsewhere.

Brandis says that trees 12 years old on an average attain a girth of 2–3 ft., and that a tree 15 years old measured 4 ft. 10 in. in girth. In Baluchistan various measurements in coppice coupes have been recorded in recent years. These apply at least in part to this species, but probably other species are included as well. In the Popalzai state forest coppice-shoots 7 months old had a minimum and maximum height of 2½ ft. and 5 ft. respectively, while those 1½ years old had an average height of 6 ft. Measurements made from 1910–11 to 1915–16 in coppice coupes in the Abdulla Kheli and Nari Bank forests gave the following results:

Age in years.	Maximum height.
1	12 ft. 9 in.
2	16 ft. 6 in.
3	15 ft. 0 in., and 17 ft. 0 in.
4	17 ft. 0 in., 19 ft. 0 in., and 20 ft. 9 in.
5	19 ft. 0 in., 22 ft. 6 in., and 27 ft. 0 in.
6	17 ft. 0 in., 22 ft. 6 in., and 27 ft. 0 in.
7	19 ft. 2 in., 22 ft. 9 in., and 27 ft. 0 in.
8	22 ft. 6 in., 22 ft. 9 in., and 27 ft. 8 in.
9	22 ft. 6 in., and 27 ft. 0 in.
10	22 ft. 11 in.
11	22 ft. 8 in.

These figures indicate that for the first few years the growth is very rapid, but that it soon begins to fall off: the trees originally felled had a maximum height of 30 ft.

ORDER VII. GUTTIFERAE

An important order of trees, chiefly evergreen, with opposite glabrous, usually leathery leaves. The trees are characteristic mainly of tropical evergreen forests, and include some useful timber-yielding species. Several of the numerous species of *Garcinia*, which are characteristically shade-bearing, furnish the pigment known as gamboge, which is exuded from cut surfaces in the cortex in the form of a yellow resinous juice: some of the species produce edible fruits, notably *G. Mangostana*, Linn., the mangosteen. Of timber trees the most important are ***Mesua ferrea***, Linn., ***Poeciloneuron indicum***,

Bedd., and some of the species of *Calophyllum* which furnish timber used for **masts and spars.**

Genera 1. CALOPHYLLUM, Linn.; 2. POECILONEURON, Bedd.; 3. MESUA, Linn.

1. CALOPHYLLUM, Linn.

Evergreen trees with shining coriaceous leaves. Besides the two described below may be mentioned *C. polyanthum*, Wall., of the moist forests of northern and eastern Bengal, Assam, Chittagong, and the Martaban hills; *C. Wightianum*, Wall., of the Western Ghats, often on the banks of streams; and *C. spectabile*, Willd., a tall tree of Tenasserim and the Andamans.

Species 1. *C. tomentosum*, Wight; 2. *C. Inophyllum*, Linn.

1. **Calophyllum tomentosum,** Wight. Syn. *C. elatum*, Bedd. Poon. Vern. *Poon*, Mal.; *Pongu*, Tam.; *Nagari*, Mar.; *Surhoni, siri, poone, bobbi*, Kan.

A very large evergreen tree with a straight cylindrical stem. Bark yellowish, with long wavy vertical fissures which readily distinguish the species (Talbot). According to Talbot it attains a great size in North Kanara, where trees 150 ft. high with a girth of 15 ft. at breast height are not uncommon. The timber is used for masts and spars and in bridge construction, but trees are far less plentiful than formerly, having been largely cleared for coffee plantations last century, as well as sought after for masts and spars.

DISTRIBUTION AND HABITAT. Western Ghats from North Kanara southwards, both on the western slopes and in Mysore and Coorg, the Palni and Anamalai hills up to 5,000 ft., always in moist evergreen forest and 'sholas', never in dry deciduous forest. Talbot says that in North Kanara it is practically restricted to the forests about Mulamane on the Gairsoppah Ghat, where it is locally common. In its natural habitat the absolute maximum shade temperature varies from 90° to 100° F., the absolute minimum from 40° to 60° F., and the rainfall from 80 to 170 in. or more.

FLOWERING AND FRUITING. The white scented flowers appear in February–March, and the fruit, an ovoid drupe about 1 in. long, ripens in May–June.

SILVICULTURAL CHARACTERS. The tree is a shade-bearer: it is sensitive to fire, and is encouraged by fire-protection. The seed germinates early in the rains, soon after falling, and the seedlings appear freely in the shade of the overhead cover.

2. **Calophyllum Inophyllum,** Linn. Alexandrian laurel. Vern. *Sultana champa*, Hind.; *Pinnai, punnai*, Tam.; *Undi*, Mar.; *Wuma*, Kan.; *Punna*, Tel., Mal.; *Pônnyet*, Burm.

A moderate-sized very ornamental evergreen tree with short thick, often crooked bole, dark brown or blackish bark, handsome white flowers and dense dark green shiny foliage. It furnishes a useful timber, and the seeds yield an oil used for burning.

DISTRIBUTION AND HABITAT. Along the east and west coasts of the Indian Peninsula, Burma, and the Andamans. It is essentially a littoral species, growing down to the edge of the sea. It grows best on deep soil near the coast, and will thrive on pure sand. Talbot says it is common in North Kanara on the sandy coast laterite soil just above high-water mark, often associated with *Anacardium occidentale*, *Salvadora persica*, *Erythrina indica*, *Ficus tomentosa*, *Pongamia glabra*, and other littoral species. **In the Andamans** it is characteristic of the mixed forests of the littoral fringe on raised beaches or deposits of sea sand; here it is found associated with ***Afzelia bijuga***, *Mimusops littoralis*, *Thespesia populnea*, *Terminalia Catappa*, ***Pongamia glabra***, *Erythrina indica*, *Hibiscus tiliaceus*, *Heritiera littoralis*, and other species.

FLOWERING AND FRUITING. According to Talbot, in North Kanara the white flowers appear in the cold season, and the fruit, a yellow or green drupe about 1–1½ in. in diameter, ripens about March. Bourdillon says that in Travancore the flowers appear in March–April and the fruits ripen in May–June, but that flowers and fruits are found at other seasons, as the tree has one large and two small crops every year. About 6 fruit-stones weigh 1 oz.; the seeds are very oily, quickly losing their germinative power. The fruits are readily eaten by bats, which disseminate the seeds.

SILVICULTURAL CHARACTERS. The tree is said to be brittle and liable to damage by wind. It can be raised without difficulty from seed provided the seed is sown soon after ripening.

2. POECILONEURON, Bedd.

Poeciloneuron indicum, Bedd. Vern. *Balgi*, *kirballi*, Kan.; *Puthan kolli*, Tam.

A large evergreen tree with a fairly straight bole, which attains a girth of 10 ft. or more. The larger trees are often buttressed, and sometimes have the appearance of being raised above the ground owing to the soil having been washed away from around the roots. It has a very hard dark red wood, which is used for building and has given fairly good results for railway sleepers.

DISTRIBUTION AND HABITAT. Evergreen forests of the Western Ghats from South Canara southwards, from 1,500 to 4,000 ft. In South Canara it extends over the crest of the *ghats* into Mysore, where it is common in the adjacent forests. Mr. Foulkes notes that in South Canara it is for practical purposes found only in certain sharply defined patches aggregating nearly 2,300 acres and situated mainly on the *ghat* slopes. Bourdillon says that it is common in the south of Travancore at elevations of 1,000–3,000 ft., but less common in the north, and that it is generally found in clumps growing on wind-swept ridges. The tree grows more or less gregariously, sometimes forming almost pure crops. Mr. Foulkes estimated, from partial enumerations in 1902, that in 2,300 acres in South Canara there were some 11,400 mature trees 2 ft. in diameter and over, distributed at the rate of 0·2 to 8·5 mature trees per acre. Mr. Gass records the following results of countings made in 1898 in three plots of 1 acre each:

(1) Total 158 trees, varying in girth from 1 ft. to 10 ft.
(2) ,, 291 ,, ,, ,, ,, ,, 1 ft. to 6 ft.
(3) ,, 79 ,, ,, ,, ,, ,, 1 ft. to over 6 ft.

The first plot was in Mysore, and the other two were in South Canara.

In the natural habitat of this tree the absolute maximum shade temperature varies from 90° to 98° F., the absolute minimum from 48° to 60° F., and the normal rainfall from 80 to 180 in.

FLOWERING AND FRUITING. The yellowish-white flowers in terminal panicles appear from December to April, and the fruit ripens from June to August. The seeds appear to lose their vitality quickly: seeds received from South Canara in 1912 had for the most part gone bad by the time they reached Dehra Dun, and although 24 selected seeds were sown at once, only 3 proved fertile. Bourdillon says it seeds freely and reproduces well in Travancore.

THE SEEDLING. The seeds just referred to were sown in open seed-beds in July, and germinated 1½ months later. At first the growth of the seedlings was rapid, a height of 7 in. being reached in ten days. Afterwards growth was slow, and the seedlings suffered from frost in the winter, when growth ceased. New growth commenced in May, but the plants died off in July. In their early stages the seedlings have a resemblance to those of the mango, except that the leaves are more leathery and the venation is not so well marked.

SILVICULTURAL CHARACTERS. The tree is a shade-bearer. It reproduces abundantly from seed, and also coppices well. It is very sensitive to fire, and benefits greatly from fire-protection.

3. MESUA, Linn.

Mesua ferrea, Linn. Syn. *M. coromandelina*, Wight; *M. pedunculata*, Wight; *M. speciosa*, Choisy; *M. Roxburghii*, Wight; *M. sclerophylla*, Thw.; *M. pulchella*, Pl. and Trian. Ironwood of Assam. Vern. *Nahor*, Ass.; *Nageswar*, Beng.; *Naga kesara*, Tel.; *Nagchampa*, Mar.; *Naga-sampige*, Kan.; *Atha*, Coorg; *Nangal*, Tam.; *Gangaw*, Burm.

A moderate-sized to large handsome evergreen tree, often buttressed at the base, with a dense conical crown of glossy leaves, their under surface glaucous with a waxy bloom. Bark fairly thin, reddish brown, red within, exfoliating in flat thin flakes. Wood dark red, extremely hard, very strong, durable but sometimes liable to dry rot, used for railway sleepers, bridge-construction, and many other purposes.

DISTRIBUTION AND HABITAT. The western Duars, Assam, Khasi hills, Chittagong, Upper Burma, Tenasserim, Andamans, hills of western and southern India. Often cultivated, especially round Buddhist monasteries. In the Duars the tree is very local, a patch occurring in the Upper Tondu forest of the Jalpaiguri forest division and another in the Tista division; the latter is probably the western limit of this species in the Bengal-Assam tract. In the Abor country it exists in small quantities in the Dihong valley (Milroy). In Bhutan it occurs to a limited extent among the low hills east of the Manas river (Jacob). In Upper Burma it is found wild, as far as is known, only in the far north, while it is said to be common in parts of Tenasserim. In the Indian Peninsula it is found in limited quantity in the tropical evergreen forests of the Western Ghats from North Kanara southwards. It is more abundant in Assam than elsewhere, and is found in suitable localities throughout that province, where it is one of the most important timber trees: in the Brahmaputra and Surma valleys it occurs at various elevations from the level of the plains up to nearly 3,000 ft. In the Andamans it is common on some of the higher hills, in evergreen forest.

Mesua ferrea is a tropical or semi-tropical tree: in its natural habitat the climate is moist, warm, and equable, the rainfall varying from 80 to 200 in.

or more, the absolute maximum shade temperature from 95° to 103° F., and the absolute minimum from 40° to 60° F.

The tree occurs on flat, gently undulating, or hilly ground, but not on low-lying badly drained land. It requires good drainage as well as a deep moist fertile soil: stiff clay is unsuitable. In Assam it occurs in the Sibsagar district on deep rich loam both on well-drained flat alluvial ground at an elevation of 310 ft., and on gently undulating ground with a subsoil of ferruginous gravel or sandstone. In the Jokai reserve, Lakhimpur, it is found in abundance on fertile sandy loam at an elevation of 450 ft. on well-drained flat alluvial ground raised above the level of river floods. In the Garo hills it forms a belt along the slopes of the central range at elevations of 1,000 to 3,000 ft., chiefly in damp sheltered localities on deep loam resulting largely from the decomposition of metamorphic rocks. In Burma it occurs in similar localities on metamorphic or sandstone formations.

Mesua ferrea is characteristically found in moist evergreen or semi-evergreen forest, either scattered or in more or less pure patches or belts of greater or less extent. It is associated with a large number of different species, many evergreen and some deciduous; in Assam some of the chief of these are *Artocarpus Chaplasha*, *Amoora Wallichii*, *Cedrela Toona*, *Quercus lanceaefolia*, *Alstonia scholaris*, *Dysoxylum binectariferum*, *Sterculia alata*, *Dichopsis polyantha*, *Gmelina arborea*, *Lagerstroemia Flos-Reginae*, *Terminalia myriocarpa*, *T. Chebula*, *Stereospermum chelonoides*, *Eugenia Jambolana*, *Dillenia indica*, *Cinnamomum Cecidodaphne*, *Dipterocarpus pilosus*, *Shorea assamica*, and many others. There is often an evergreen undergrowth, while climbers are prevalent. In the Assam forests the proportion of *Mesua* (locally called *nahor*) to other species may vary considerably. In the Namhor reserve, Sibsagar, Mr. A. R. Dicks has estimated that it forms 5 per cent. of the crop on the high alluvium on which it occurs. In the working plan for the Jokai reserve, Lakhimpur, Mr. F. H. Cavendish states that the tree occurs only on the higher alluvium, where it is found in almost pure patches up to 100 acres or more in area, which gradually merge into mixed evergreen forest. He divides the forest on this ground into three classes as follows:

(1) *Nahor* dominant, forming 30–80 per cent. of the stock: about 1,000 acres.

(2) Evergreen forest in which *nahor* is scattered more sparsely: about 500 acres.

(3) Evergreen forest containing a mixture of various species where *nahor* is hardly found: about 2,100 acres.

In this forest a complete enumeration of *nahor* trees over 709 acres where this was the dominant species gave the following results:

Trees over 6 ft. in girth	192 or 0·27 per acre
„ 4–6 ft. in girth	1,857 or 2·6 „ „
„ 2–4 ft. in girth	7,660 or 10·8 „ „

Saplings and seedlings below 2 ft. in girth numerous.

Peal, quoted by Gamble, gives the following account of the spread of the *nahor* in Assam from trees planted by the Burmese when they occupied that province: 'The forest, if properly studied, often yields information of a peculiar kind: thus the *nahor* gives a clue to the density of the population compared to what we see now. The large, old, and crooked branching *nahor* trees clearly indicate that when young the country now forest was then open. They are often along the sides of old "bunds" (embankments) in dense forest, and evidently planted, and from the seed the *nahor* forest has sprung up, and it is generally as straight as the old trees are the reverse.'

LEAF-SHEDDING, FLOWERING, AND FRUITING. The old leaves fall during the cold season, and the new flush of red or pink leaves appears towards the end of that season, usually from about the end of February in Assam. The large scented white flowers, 2 in. or more in diameter, with numerous prominent yellow stamens, appear from the end of February to April, or in Assam up to May or even June (January–April in Travancore, Bourdillon); when the tree is in flower it is a gorgeous sight with its masses of white blossoms, which are visited by innumerable bees and other insects. The time at which the fruit ripens appears to vary. Talbot says May (North Kanara), Kurz says May–June (Burma), and Bourdillon says October–March (Travancore). In Assam it ripens from August to October. The fruit is ovoid, pointed, somewhat woody, about 1–1·5 in. long, two-valved, containing 1–4 seeds. The seeds (Fig. 9, *a*) are 0·8–1·1 in. long, ovoid or irregularly hemispherical, pointed, with angular sides, smooth, reddish brown; testa hard but somewhat brittle. About 150–200 seeds weigh 1 lb. The seeds are very oily and soon lose their vitality. The tree ordinarily commences to produce fertile seed at from fifteen to twenty years of age. Isolated trees flower and seed abundantly almost every year, while in the forest good seed-years take place at frequent intervals.

GERMINATION (Fig. 9, *b–e*). Hypogeous. The testa of the seed splits and the radicle emerges from the blunter end and descends. Meanwhile the cotyledonary petioles elongate rapidly, enabling the plumule to emerge and ascend. The fleshy cotyledons remain below the ground within the testa, remaining attached to the seedling for several months and supplying it with nutriment.

THE SEEDLING (Fig. 9).

Roots: primary root moderately long, thick, terete, tapering, brown, wiry: lateral roots numerous, long, fibrous, much branched. *Hypocotyl* scarcely distinguishable from root, 0·1 in. long or less, stout, subterranean. *Cotyledons* petiolate, subterranean, remaining within the testa: petiole 0·2–0·3 in. long, thick, at first fleshy, afterwards woody, inner surface flattened: lamina 0·9–1·1 in. by 0·6–0·8 in., thick, fleshy, and oily, unequally ovate, outer surface rounded, inner flattened in contact. *Stem* erect, terete, wiry, green, glabrous; first internode, between cotyledons and first foliage leaves, 4–7 in. long, subsequent internodes much shorter, about 0·7–1·5 in.; new shoots likewise commence with a long internode, subsequent internodes being shorter, up to 2·5 in. in seedlings of the second year. *Leaves* simple, opposite, exstipulate; first few usually rudimentary and scale-like. Petiole 0·2–0·3 in. long, glabrous. Lamina 1·7–4 in. by 0·6–0·9 in., elliptical lanceolate, acuminate, base acute, entire, coriaceous, dark green and shining above, glaucous beneath with a waxy bloom; young leaves delicate, drooping, pink or pale green; venation pinnate, midrib distinct, lateral veins numerous, fine, and close together, running nearly at right angles to midrib.

The growth of the seedling is slow to moderate, a height of 6–10 in. being ordinarily attained in the first season, while thereafter the growth is at the rate of a few inches up to about a foot a year. The seedling stands a considerable amount of shade, but dislikes suppression by weeds. It is sensitive to cold and drought, and under forest conditions demands shelter from the sun.

SILVICULTURAL CHARACTERS. *Mesua ferrea* is a strong shade-bearer, particularly in youth. Frost is practically unknown in the natural habitat of the tree, and in the sheltered position in which the young plants grow they are never exposed to the risk of frost. If planted outside its natural habitat in places subject to frost, it has been found to be very tender, and the same applies as regards drought. Fire does not ordinarily occur in the type of forest in which it is found. In certain localities the trees are subject to the attacks of what is believed to be a root fungus, which kills them off in groups: so far the sporophores have not been found, and the fungus has not been specially studied or identified.

The coppicing power of the tree appears to vary. In coppice coupes in Assam it is reported not to coppice freely. Rai Bahadur Upendranath Kanjilal informs me that trees coppiced in the Holangapar reserve, Sibsagar, which were from 12 to 24 in. in girth, entirely failed to coppice. On the other hand, Jogeswar Sur wrote in 1883[1]: 'That *nageswar* coppices freely admits of no doubt, and I have seen a young tree when burnt down throw out strong shoots from the collum. Again, I once tried to kill three young plants growing in front of a rest-house at Kulsi by cutting them flush with the ground, but as often as they were cut back they threw out new shoots. A tree 15 years old in a garden at Calcutta was felled, and the stool sent up new shoots.'

NATURAL REPRODUCTION. In forests where it occurs *Mesua ferrea* regenerates more profusely than almost any of its associates, partly because of its abundant seeding, and partly owing to the capacity of the seedlings for standing, and even requiring, a considerable amount of shade. The essential conditions for germination and early development are a high degree of moisture and protection from the sun: seeds lying in the open exposed to the sun soon crack and go bad. A good seed-year does not necessarily result in plentiful regeneration, since the seed is liable to the attacks of weevils, and the seed crop may suffer seriously in consequence. On the ground the seeds are readily devoured by pigs, porcupines, and other animals, and where this is permitted they are also collected by the local inhabitants for burning. The oily seeds are strung like beads on a thin piece of split bamboo and then lighted, when they burn like a candle. Mr. Kanjilal notes that in Sibsagar natural reproduction takes place freely in swampy localities under the cover of dillenias and laurels, the seed being deposited by water, and that judging by the ages of the seedlings, profuse regeneration takes place every four or five years. Two important factors for successful reproduction are a dominant condition of the seed-bearers and freedom of the seedlings from suppression by a dense undergrowth or masses of climbers. Where the *nahor* trees are dominant, with free well-developed crowns capable of producing a plentiful crop of seed, there is usually no difficulty in obtaining sufficient regeneration, but where they form an under-story to larger trees of other species and owing to their dominated position are unable to produce seed in quantity, the regeneration is usually poor. This indicates the necessity for carrying out thinnings in the

---

[1] Ind. Forester, ix (1883), p. 609.

overwood, together with climber-cutting, in order to free the crowns of the *nahor* seed-bearers. Again, where, as is often the case, there is a thick evergreen undergrowth or an under-story of various poles and shrubs covered with a dense mass of climbers, although *nahor* seedlings and saplings are capable of struggling amongst this dense growth to a remarkable extent, systematic climber-cutting and cleaning has proved to be most beneficial to the establishment of this regeneration. In general, then, it may be said that there is no difficulty in obtaining ample natural regeneration by means of systematic thinnings and climber-cutting, with cleaning in the undergrowth where necessary. With this assistance the shade-bearing *nahor* seedlings and saplings have no difficulty in competing successfully with their faster-growing but more light-demanding associates.

ARTIFICIAL REPRODUCTION. The only available record of a forest plantation of *Mesua ferrea* is that formed at Ohguri in the Nambor reserve, Sibsagar division, Assam, between the years 1876–7 and 1882–3. This plantation, which never justified the expenditure on it, was eventually abandoned. It was formed by sowing seeds of *Mesua ferrea*, *Lagerstroemia Flos-Reginae*, and *Cedrela Toona* in lines 6 ft. apart: the proportion of each species sown is not known. In 1903 Mr. Dicks reported that the plantation, the average age of which was then twenty-four years, was very densely stocked with young poles, but that the *Lagerstroemia* greatly outnumbered the *Mesua*: presumably the *Cedrela* did not succeed. Neglecting what were obviously pre-existing natural saplings from neighbouring seed-bearers, the average girth of the dominant and sub-dominant trees was found to be 2 ft. Most of the trees above 2 ft. in girth were found to have seeded.

Considering the facility with which natural reproduction can be secured, the experience gained from this plantation indicates that the meagre success attained would hardly justify such a form of artificial reproduction on a large scale, though it is possible that seed dibbled under the shade of forest of suitable type, if this could be done cheaply, might be a means of extending the area of *nahor* forest where this species is absent or scanty.

The raising of plants for planting out along roadsides or in gardens presents no special difficulty. The seed should be sown as soon after collection as possible and well covered with earth in the nursery beds; the latter should be in a shady situation and should be kept moist, care being taken to avoid caking of the soil. A fairly long stout taproot is developed by the seedling, but with ordinary care there is no special difficulty in transplanting, which may be carried out from the first to the third rains after sowing, according to the size of plants required. Watering should be carried out in the dry season for at least two years after transplanting.

SILVICULTURAL TREATMENT. In Assam it has been usual to work the forests containing *nahor* under selection and improvement fellings in which this tree is the one most favoured. In selection fellings a minimum girth limit of 6 ft. is commonly adopted, the corresponding age being assumed to be ninety years. From what has been mentioned above under 'natural reproduction', it is obvious that systematic freeing of *nahor* trees in the overwood, combined with climber-cutting and with cleaning where necessary in the underwood, is a great stimulus to the establishment of natural reproduction, and the concentration of such operations for certain periods over definite manageable blocks is likely to increase considerably the proportion of this valuable species. The dibbling of seed where *nahor* is sparse or absent has been suggested above.

RATE OF GROWTH. Observations of trees planted in gardens show that the rate of growth is decidedly slow. Authentic statistics for forest use are scanty, and until the results of periodic measurements in sample plots are available they will remain so. Concentric rings of darker tissue, it is true, are visible on a cross-section, but they cannot be relied on for furnishing accurate data; it is not even certain whether or not they represent annual rings. The measurements noted above for the Ohguri plantation, Sibsagar, show an average girth of 2 ft. in twenty-four years, representing a mean annual girth increment of 1 in., which is by no means slow. The tree, however, does not produce a very long straight bole, so that the out-turn development is probably less than the increase in girth might indicate. In the Nambor forest, Sibsagar, it was found that trees 6 ft. in girth yielded on an average 18 metre-gauge sleepers.

In his working plan for the Nambor forest Mr. Dicks quotes a further instance of a small group of *nahor* trees surrounded by other trees behind the circuit-house at Sibsagar. These trees are said to have been planted in 1858–60, and had an average girth of 4 ft. 2 in. when forty-eight years old. No accurate data are available for older trees. There is, however, a general tradition, supported by the presence of temples and tanks, that the Nambor forest was under cultivation prior to the Burmese invasion at the beginning of last century, and that the land relapsed into jungle when the local population was driven out. At the commencement of the present century there were a fair number of *nahor* trees 7 to 8 ft. in girth, but very few above 8 ft. If this tradition be correct, it may thus be assumed that it takes 100 years to produce an average girth of 7½ ft. The following provisional data are thus available:

Age in years.	Girth. ft.	in.
24	2	0
48	4	2
100	7	6

Making allowance for possible errors, Mr. Dieks makes the following rough estimate of the rate of growth, based on the above data:

Girth at breast height. ft.	in.	Age.
1	6	20
3	0	40
4	6	60
6	0	90

These figures must be considered as purely tentative.

ORDER VIII. TERNSTROEMIACEAE

This order, important mainly as being the one to which the tea-plant belongs, contains several trees of local interest, chiefly hill species. The only one of special importance is *Schima Wallichii*, Choisy.

SCHIMA, Reinw.

Schima Wallichii, Choisy. Syn. *Gordonia integrifolia*, Roxb. Vern. *Chilauni*, Nep., Sikkim, Duars; *Mukria sál*, Ass.; *Laukya*, Burm.

A large handsome evergreen tree, attaining a height of 80–100 ft. and a girth of 10 ft. or more, with a tall straight bole and a dense rounded crown. Bark dark grey with deep vertical fissures. Wood used for building and other purposes, but apt to warp and split. An important tree in the outer hills of the eastern Himalaya and in the Duars.

DISTRIBUTION AND HABITAT. The eastern Himalaya and sub-Himalayan tract from Nepal eastwards, Assam, Khasi hills, Manipur, hills of Chittagong and of Upper Burma. It is often more or less gregarious. In the eastern Himalaya it ascends to about 5,000 ft. or slightly higher, and extends outside the base of the hills for some miles. In the Duars it is common in places mixed with sal on deep rich soil, extending for several miles from the base of the hills down to an elevation of about 1,000 ft. Here both species attain very fine dimensions: it is noticeable, indeed, that *Schima* in this tract is a particularly good indicator of very fine quality of sal forest. Here the rainfall varies from about 120 to 160 in. The tree is abundant in the foot-hills, where it is sometimes the prevailing species, and reaches large dimensions; towards its upper limit it tends to become stunted. It is common in various forest tracts in Assam, where it is sometimes gregarious and reaches a large size. Mr. Jacob[1] states that it is the most common tree in the outer hills in western Bhutan up to 4,000 ft., but is less common in eastern Bhutan. In the hills of Upper Burma it is not found below 3,000 ft., and occurs associated with oaks and other extra-tropical trees: it is common on the Maymyo plateau.

In its natural habitat the absolute maximum shade temperature ordinarily varies from 90° to 100° F., the absolute minimum from 30° to 40° F., and the normal rainfall from 55 to 200 in.

FLOWERING AND FRUITING. The fragrant showy white flowers appear from April to June. The fruit appears to ripen at different seasons according to locality and elevation. Gamble (Darjeeling list) says November–December: Brandis says cold season: Copeland (Manual of Arboriculture for Burma) says April. In the Duars (elevation 1,000 ft.) I have collected ripe capsules, which were dehiscing and shedding their seed, at the end of January and during February. The capsules are hard, woody, globose, five-valved, 0·5–0·7 in. in diameter. The seed is flat, pale greyish brown, with a papery wing extending round about three-quarters of the periphery, 0·35–0·5 in. by 0·2–0·3 in. including the wing, the whole reniform in outline. The seeds are light and are spread by the wind: parrots eat them on the trees and break off the capsules, which fall in quantities to the ground. The seed can be extracted from the woody capsules by collecting the latter immediately before opening and placing them in the sun for a few days, when they open and the seed is easily shaken out. Seed-years appear to be common: records for four successive years in the Tista division, Bengal, and in the Ruby Mines division, Upper Burma, showed good seeding.

---

[1] Report on the Forests of Bhutan, 1912.

SILVICULTURAL CHARACTERS. The tree is a moderate light-demander; it regenerates abundantly where sufficient light is admitted for the development of the seedlings, which are sometimes found in great profusion. It coppices well.

ORDER IX. DIPTEROCARPACEAE

This order, which contains 325 known species of trees (rarely shrubs) in 16 genera, is confined to the Indo-Malayan region. So far as richness in species is concerned, India and Burma cannot compare with the Malay Archipelago, but in our region the silvicultural and economic importance of this order is very great, partly because it contains several valuable timber trees and partly because some of these are gregarious in character, simplifying scientific working and cheapening the cost of felling and extraction. Most species are rich in resin or wood-oil, while a valuable form of camphor is yielded by the camphor tree of Borneo (*Dryobalanops aromatica*, Gaertn. f.), which, however, does not occur in our region. Most of the dipterocarps are characterized by tall straight cylindrical boles without branches for a considerable distance from the ground. This characteristic is particularly well marked in the larger species of *Dipterocarpus* and *Hopea*, whose crowns, elevated on long clean stems, tower above the surrounding forest.

LEAF-SHEDDING, FLOWERING, AND FRUITING. Some of the dipterocarps are wholly evergreen, particularly the large species of *Dipterocarpus* and *Hopea* found in tropical evergreen forests. The others are chiefly near the border-line between evergreen and deciduous, approaching the former state in moist fertile localities and the latter in poor dry situations, while certain of these become wholly deciduous in dry regions. As a rule the leaves are shed towards the end of the cold season or early in the hot season, and in the majority of cases flowering takes place during or at the end of the period of leaf-fall; in *Dipterocarpus obtusifolius* the flowers appear before the leaves commence falling. The flowers of the dipterocarps are adapted for insect pollination, some being scented, some large and showy as in *Dipterocarpus*, while in some species they are produced in large quantities when the trees are out of leaf. The majority of the dipterocarps are easily recognized from the fact that 2 or more of the 5 calyx lobes become enlarged in the fruit into wings: there are 2 such wings in *Dipterocarpus* and *Hopea*, 3 or more in *Pentacme* and *Shorea*, and 5 in *Parashorea*. In the great majority of cases the fruits fall towards the end of the hot season or at the commencement of the rainy season, and germinate almost at once. Except possibly in the case of those species which occur in moist tropical forest, in which the fruits fall on damp ground protected from the sun, an essential condition for the germination of the seed is the occurrence of timely rain, failing which the whole seed-crop may come to nothing. Seed is ordinarily produced to some extent every year, while good seed-years occur at frequent intervals, and in the majority of species the trees are laden with winged fruits, which in the case of the lighter-fruited species are carried to a considerable distance by the strong winds which occur in many localities towards the end of the hot season. The fruits are not in any way protected against damage by fire, but such protection is not required, since they fall mainly after the season of forest fires. A good seed-year followed by timely rain results in an abundant crop of seedlings. The fruits of most if not all species are buoyant in water, and this no doubt aids their spread in the case of those which grow in moist localities near streams.

Germination may be either hypogeous, as in the case of the larger and heavier fruits (*Dipterocarpus*, *Shorea*), or epigeous, as in *Hopea*, the cotyledons escaping from the fruit and being carried above ground.

The following list, giving the flowering and fruiting seasons of the chief dipterocarps in the Indo-Burman region, illustrates the remarkable similarity between the fruiting seasons of the various species and their coincidence with the commencement of the rainy season:

	Flowering.	*Fruiting.*
Dipterocarpus turbinatus, Gaertn. f.	March–April	May–June (Burma and Assam).
D. alatus, Roxb.	February–March	May–June.
D. indicus, Bedd.	December–January	May–July (Coorg). April–May (Travancore, Bourdillon).
D. Bourdilloni, Brandis	January–February	May–June.
D. pilosus, Roxb.	?	April (Brandis). February–March (Assam, Kanjilal).
D. Griffithii, Miq.	?	May (Kurz).
D. tuberculatus, Roxb.	March–April	May.
D. costatus, Gaertn. f.	March	April–May.
D. obtusifolius, Teysm.	November–January March–April	March–April (Siam, Ryan and Kerr). April–May (Burma, Kurz).
Hopea odorata, Roxb.	March–April	May–June.
H. parviflora, Bedd.	January–February	May–June (Bourdillon).
H. Wightiana, Wall.	March–April	May June.
H. glabra, W. and A. (*H. Wightiana* var. *glabra*, Bedd.)	January–February	June–July.
H. racophloea, Dyer	April–May	June–July.
Pentacme suavis, A. DC.	March	May–June.
Shorea robusta, Gaertn. f.	March–April	June.
S. obtusa, Wall.	March	May.
S. Tumbuggaia, Roxb.	March–April	June–July.
S. Talura, Roxb.	February–March	April–May.
S. assamica, Dyer	September	January–February (Assam).
Parashorea stellata, Kurz	March–April (Brandis)	April–May (Kurz).
Balanocarpus utilis, Bedd.	May	Rainy season.
Vatica Roxburghiana, Blume	February–March	June.
Vateria indica, Linn.	January–March	May–July.

In all species which have been studied to any extent the maximum growth takes place for about a month or two after the new leaves appear, that is, in the hot season. In some cases growth continues to a small extent during the rains, particularly in young trees and coppice-shoots, but in others it ceases entirely before the end of the hot season.

HYGROPHILOUS AND XEROPHILOUS TYPES. The dipterocarps of the Indo-Burman region may be divided into two broad types: (1) the hygrophilous or sporadic type, the species of which occur on fertile ground in moist tropical usually evergreen forest, and (2) the xerophilous or gregarious type, in which the species are adapted to grow in dry or moderately dry localities and to endure conditions under which species of the hygrophilous type would succumb. The terms 'hygrophilous' and 'xerophilous' are here used in a purely relative sense. Strictly speaking it would be more correct to say that dipterocarps in general are mesophytic, but are divisible into two main types, of which one has more xerophilous characteristics than the other: the line of distinction between the two types, however, is sufficiently well marked to warrant the adoption of two terms conveying the idea of contrast.

1. *The hygrophilous type.* This type comprises the largest of the dipterocarps, for example *Dipterocarpus turbinatus*, *D. indicus*, *D. alatus*, *D. pilosus*, *D. Griffithii*, all species of *Hopea* and *Balanocarpus*, *Parashorea stellata*, and *Vateria indica*. *Shorea assamica* and *S. Talura* may also be placed in this type. The trees of this type grow on damp rich soil in tropical moist or evergreen forest, and are themselves typically evergreen. They occur sporadically, and though at times they form pure groups or patches of varying extent, they are not gregarious over large areas. This sporadic growth is due to the fact that there are a large number of other species competing for the ground and thus creating conditions adverse to gregarious growth: outside our region some of the species of this type are said to grow gregariously. The trees are shade-bearing, at all events in youth; their existence depends on this character, as the forest in which they occur is usually dense. As a rule the bark is comparatively thin and smooth, not thick, rough, and deeply fissured. The trees are thus ill-adapted to withstand damage by fire, to which, however, they are not ordinarily subjected in the evergreen forests in which they grow: saplings which are burnt down have poor power of recovery, and unless only slightly scorched are usually killed outright. As far as is known most of the trees coppice badly or not at all: Beddome, however, says that *Hopea Wightiana*, var. *glabra*, coppices well. The forests in which trees of this type occur are not characterized by the presence of numerous forest grasses, but as a rule by a dense evergreen undergrowth.

2. *The xerophilous type.* This type includes *Dipterocarpus tuberculatus*, *D. obtusifolius*, *Pentacme suavis*, and most species of *Shorea*, though *S. assamica* and *S. Talura* belong rather to the hygrophilous type. Although at times sporadic, the trees often grow gregariously over areas of varying extent; this gregarious condition is due not only to the fact that seed is produced in large quantities, but even more to the fact that the conditions under which they grow are less unfavourable to them than to the majority of the species with which they are associated, and the struggle for existence against other species is less severe than in the hygrophilous type. Although they extend into regions of heavy rainfall, the species of this type cannot establish themselves in moist evergreen forest, but cling to localities with drier types of soil and

subsoil; here, however, they become dominant and gregarious, since they are specially adapted to resist the dangers usually prevalent in comparatively dry situations, and can survive these dangers to a greater degree than the majority of their associates. The trees of this type are either deciduous or approach the deciduous state; in dry hot situations they may become entirely deciduous, *Pentacme suavis*, for example, remaining leafless for a month or more in such places, whereas in moister and more fertile localities it does not as a rule become quite leafless. In this respect adaptation to environment is strongly marked. The trees are characterized by thick, rough, often deeply furrowed bark. They are light-demanders or tend towards light-demanding rather than towards shade-bearing habits: thus young growth tends to establish itself in even-aged patches in gaps where sufficient light is admitted. The localities in which the crops establish themselves are characterized not by a dense evergreen undergrowth but by the presence of various forest grasses, which are of great importance to the economy of the crop. These grasses often form extensive savannah tracts within the forests, into which, if these tracts are well drained, the trees gradually spread. The presence of so much grass within the forest is the cause of severe fires, but the dipterocarps in these tracts are specially adapted to resist the effects of fire, not only by reason of their thick bark, but also owing to their great power of recovery from injury: seedlings and saplings may be burnt down year after year, but continue to develop a strong woody growth underground, and eventually establish themselves in spite of fire. Up to a moderate size the species of this type coppice well.

Among adaptations for overcoming adverse conditions, one of the most noteworthy is that exhibited by the sal (*Shorea robusta*) in the annual 'dying back' of seedlings, a phenomenon which may be observed in the case of various species of Indian trees growing in dry regions. Under optimum conditions of soil and moisture the sal, if not exposed to injury by frost, fire, or other agencies, does not die back but shoots straight up from the seed. In the majority of cases, however, where conditions fall short of the optimum by reason of unfavourable climatic or soil factors—for example, deficiency of soil-moisture or bad soil-aeration due to excess of moisture, hardening of the soil, or other causes—the seedlings die back annually for several successive years, during which a strong root-system is developed underground until the seedling is strong enough to shoot up without further dying back. The other dipterocarps of this type have not yet been studied sufficiently to ascertain if the same phenomenon occurs in other species, but it is probable that it does occur in at least some of them in localities where conditions fall short of the optimum. Again, apart from the thick rough bark, the strongly developed root-system, and the capacity for recovery after dying back, several of the species exhibit other xerophytic adaptations against excessive heat and drought or protective devices against intense light, which is a correlated factor. Thus *Dipterocarpus tuberculatus* and *D. obtusifolius* have large sheathing stipules enclosing the buds, while the latter species possesses the capacity for storing quantities of water in its tissues during the dry season. *D. tuberculatus* trees in dry exposed situations tend to hang their leaves more or less vertically, while the leaves of *D. obtusifolius* are deeply folded between the lateral veins;

in either case the direct rays of the midday sun are warded off and excessive transpiration is minimized. The young leaves of several species, notably *Dipterocarpus tuberculatus*, *Pentacme suavis*, and *Shorea robusta*, are red or copper-coloured, while in *Pentacme suavis*, perhaps the most xerophilous of all the dipterocarps, even the older leaves often have a characteristically red colour; this coloration is a well-known protective device against intense light. Ryan and Kerr[1] point out that in the case of *Dipterocarpus tuberculatus*, *D. obtusifolius*, and *Pentacme suavis* there are two well-marked varieties, one in which the young shoots and stipules are glabrous, and the other in which they are tomentose, and that in the case of *Pentacme* the tomentose form is characteristic of dry rocky situations and the glabrous form of more fertile ground; this differentiation of localities has not yet been established in the case of the other two species.

It will thus be seen that the broad silvicultural characters of the two types are well defined. Actually the species of either type may overlap where the respective localities meet, and it is noteworthy that trees of the xerophilous type reach their best development in localities approaching in character those occupied by species of the hygrophilous type. Thus in Burma, where the dry so-called *indaing* forest meets the moist or evergreen forest, the hygrophilous trees *Dipterocarpus turbinatus* and *D. alatus* are occasionally found mixed with the xerophilous species *D. tuberculatus*, *Pentacme suavis*, and *Shorea obtusa*; here the three latter species reach very large dimensions. Again, *Shorea robusta* shows exceptionally fine development in the moist Duars tract of Bengal and Assam, where the rainfall varies from about 130 to 180 in. The tree is here in its optimum habitat, for seedlings raised from seed sown in the open do not die back but shoot rapidly upwards. There is clear evidence that the sal forests of this tract established themselves by degrees in savannah lands which were regularly burnt. Continued fire-protection for thirty to forty years, however, has entirely altered the character of the forests, introducing a previously non-existent evergreen undergrowth, increasing the soil-moisture, and decreasing the soil-aeration: in consequence of this, although the previously established crop continues to flourish, the trees seed freely and the seed germinates well, new regeneration under the altered conditions is entirely unable to establish itself, and the only possible means of regenerating the forests, which are now for the most part too damp to burn, is to clear-fell, burn the dry refuse, cultivate the soil, and regenerate artificially. The case of the Duars forests is an instructive example of the manner in which the sal, like other dipterocarps of the xerophilous type, profits by adverse conditions to establish itself gregariously where the majority of species fail to obtain a footing, and where these conditions are radically altered, ostensibly for the better, it may lead to the extermination of the once dominant species. An alteration of conditions to this extent would naturally not be possible in drier localities: it is only the moister types of xerophilous dipterocarp forest that are, so to speak, in unstable equilibrium.

STUDY OF SILVICULTURAL CHARACTERS. The general silvicultural characters of this order have been gone into at some length because the majority of the individual species have not yet received sufficient detailed study. As far as we know, however, the silvicultural affinities between the various species of the two main types of dipterocarps are strong, and the facts of which we are in possession regarding certain species may well form a starting-point for the more detailed study of other species of the same type. So far the sal has been studied in much greater detail than any other dipterocarp, and the particulars given below for this species should indicate to some extent the lines of study and methods of treatment for other species of the xerophilous type. Among further characters which experiments or observations have so far shown to be common to both types may be mentioned (1) the adverse effect of a thick layer of dead leaves on the establishment of seedlings and the advantage of burning the soil-covering in order to obtain regeneration;[1,2] (2) the advantage of fire-protection to aid the establishment of seedlings and the absolute necessity for it in the hygrophilous type;[2] (3) the advantage of light as an aid to the development of saplings even in the hygrophilous type, and more so in the xerophilous type; (4) the absence of root-suckers as a means of reproduction: if these occur at all they are quite exceptional.

---

[1] Journ. Siam Soc., viii (1).

Genera 1. DIPTEROCARPUS, Gaertn. f.; 2. HOPEA, Roxb.; 3. PENTACME, A. DC.; 4. SHOREA, Roxb.; 5. PARASHOREA, Kurz; 6. BALANOCARPUS, Bedd.; 7. VATERIA, Linn.

1. DIPTEROCARPUS, Gaertn. f.

Large, in some cases lofty, trees with straight cylindrical stems. Of the five calyx segments two develop into large wings in the fruit. This genus comprises species both of the hygrophilous and of the xerophilous types: to the former belong Nos. 1, 2, 4, and 6, and to the latter Nos. 3 and 5 of the species dealt with here.

Species 1. *D. turbinatus*, Gaertn. f.; 2. *D. indicus*, Bedd.; 3. *D. obtusifolius*, Teysm.; 4. *D. pilosus*, Roxb.; 5. *D. tuberculatus*, Roxb.; 6. *D. alatus*, Roxb.

1. **Dipterocarpus turbinatus,** Gaertn. f. Syn. *D. laevis*, Ham. Gurjun, wood-oil tree. Vern. *Gurjun*, Beng.; *Kanyin*, *kanyin-ni*, Burm. In the Andamans the name gurjun is applied indiscriminately to more than one species, namely, *D. turbinatus*, *D. Griffithii*, *D. alatus*, and probably one or two others.

A lofty evergreen tree, attaining a height of 150 ft. or more, and a girth of 15 ft. or over, with a long clean cylindrical bole and an elevated crown. Bark light grey, yellowish brown inside, exfoliating in irregular rounded flakes. Locally the wood is used mainly for boat-building, dug-out canoes, and planking; there is an export trade in it from the Andamans, and it has been well reported on in the London market. The tree is tapped for wood-oil.

DISTRIBUTION AND HABITAT. The Andamans, Cachar, Tipperah, Chittagong hills, and throughout the greater part of Burma, extending into Siam. The tree is not typically gregarious over large stretches of country like *D. tuberculatus*, though sometimes it approaches that condition in patches. It is found

---

[1] *Vide* experiments described under *Shorea robusta*, pp. 95, 96.

[2] *Vide* observations on natural reproduction and silvicultural treatment of *Dipterocarpus turbinatus*, p. 36.

in forests of the moister tropical type, evergreen or semi-evergreen, where along with a few other lofty species it towers above the rest of the forest. In Burma it is associated with *Dipterocarpus alatus*, *Mangifera* spp., *Eugenia* spp., *Lagerstroemia* spp., *Amoora*. *Sterculia alata*, *Garcinia* spp., ***Hopea odorata*** (in moister localities), *Artocarpus Chaplasha*, *A. Lakoocha*, ***Pentace burmanica***, and others, often with an undergrowth of various palms and canes.

In the Andamans it is found in evergreen forest, associated with other dipterocarps, including ***D. Griffithii***, ***D. alatus***, and ***Hopea odorata***, also with *Artocarpus Chaplasha*, *A. Gomeziana*. *Calophyllum spectabile*, ***Mimusops Elengi***, *Terminalia bialata*, *Myristica Irya*, and other trees, with a dense undergrowth of canes, climbers, and the climbing bamboo *Dinochloa andamanica*.

In its natural habitat the absolute maximum shade temperature varies from 98° to 105° F., and the absolute minimum from 45° to 60° F., the rainfall varying from 60 to over 200 in.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The old leaves are shed early in the hot season. The rose-coloured flowers appear in March–April, and the fruit ripens in May or early June (Upper Burma), germination taking place as soon as the seed falls.

SILVICULTURAL CHARACTERS. The main silvicultural characters are those of the hygrophilous type of dipterocarps (see p. 32). Notes recorded by Mr. H. R. Blanford[1] show that the tree is very sensitive to fire. In Upper Burma an area where the *tin* bamboo (*Cephalostachyum pergracile*) had flowered gregariously was burnt in 1914, after several years of fire-protection, in order to stimulate the natural regeneration of teak. In this area nearly all the young *kanyin* (*D. turbinatus*) trees up to about 10 ft. in height were killed by the fire: further observations showed similar results in other localities, saplings escaping partially only where the fire had not been fierce. The power of recovery from injury by fire is likewise poor: where a sapling is only slightly scorched it recovers, but if badly damaged it has no power of recovery from the base, as in the case of *D. tuberculatus* and other fire-resisting species. So far as is known the tree neither coppices nor produces root-suckers.

NATURAL REPRODUCTION. In Mr. Blanford's observations mentioned above it was noticed that on areas burnt after several years of fire-protection *kanyin* seedlings appeared in quantity wherever there was sufficient light for their development. There was also a great abundance of *kanyin* saplings on areas fire-protected for some years, and from their size it was concluded that they first appeared when the area was brought under fire-protection. These observations indicate that a burnt area forms an excellent germinating bed for the seed of *kanyin*, as of many other species, but that strict fire-protection is necessary if the seedlings are to establish themselves. The fruits fall after the season of fires, and in the first year the seedlings are therefore not exposed to damage from this source.

In the Andamans Mr. C. G. Rogers[2] notes that seedlings of several dipterocarps are generally found in the evergreen forests, but it is doubtful if they are able to make their way through the dense growth of climbing bamboo and creepers; he adds that the low density of sound mature trees

---

[1] Ind. Forester, xli (1915), p. 78.

[2] Report on the Exploration of the Forests in the South Andaman and other Islands, 1906.

(averaging about one per acre) seems to indicate that only a very small proportion of the seedlings which come up ever succeed in forcing their way through the dense undergrowth and reach maturity.

Silvicultural treatment. Mr. Blanford's observations indicate that the treatment to be adopted to secure natural reproduction of this and other similar dipterocarps of moist regions is to execute a heavy clearing of all cover, retaining sufficient seed-bearers, and to burn the area thoroughly next season, thereafter enforcing strict protection from fire and carrying out the necessary cleanings and thinnings.

2. **Dipterocarpus indicus**, Bedd. Vern. *Challane*, Kan.; *Kalpaini*, Coorg; *Ennei*. Tam.

A lofty evergreen tree attaining a height of 120 ft. or more and a girth of 12 ft. or over, with a tall clean cylindrical bole. Bark light grey, smooth. Wood reddish grey, somewhat rough, not very durable, used for interior construction not in contact with the ground. The tree is tapped for wood-oil. This species strongly resembles *D. turbinatus*.

Distribution and habitat. The Western Ghats from North Kanara southwards to Travancore, in evergreen forests up to 3,000 ft. The climate of this region is a humid one: the absolute maximum shade temperature varies from 95° to 100° F., the absolute minimum from 55° to 65° F., and the normal rainfall from about 80 to 200 in. or more.

Flowering and fruiting. The fragrant white flowers appear in December–January, and the fruit ripens from April to early July, according to locality. The fruit (Fig. 10, *a*) is large and somewhat heavy, with two wings about 4 in. long.

Germination (Fig. 10, *b*, *c*). Hypogeous. The radicle emerges from between the wings and curves rapidly downwards, the cotyledonary petioles meanwhile elongating to a length of about an inch, enabling the plumule to emerge from between them. The thick fleshy cotyledons remain within the fruit.

The seedling (Fig. 10).

Roots: primary root long, thick, terete, tapering, woody: lateral roots few, short, fibrous, distributed down main root. *Hypocotyl* scarcely distinguishable. *Cotyledons* subterranean: petiole 1–1·5 in. long: lamina about 1 in. long, thick, fleshy, obovate, the two conferruminate within the fruit, forming an obovoid fleshy mass. *Stem* erect, terete, woody, densely tomentose with stellate hairs, especially in the younger parts; internodes, the first (between cotyledons and first foliage leaves) 4–8 in., subsequent internodes 0·3–1 in. long. *Leaves* simple, first pair opposite, subsequent leaves alternate. Stipules 0·4–0·5 in. long, ligulate, tomentose, caducous. Petiole 0·4–0·8 in. long, stellate tomentose. Lamina 2–6 in. by 1·5–2·7 in., elliptical ovate, entire, acuminate, base rounded, upper surface glabrous, lower stellate tomentose on the principal veins, margins ciliate; lateral veins prominent, 8–12 pairs.

Seedlings 3½ years old raised from sowings under moderate shade in abandoned clearings in Coorg attained an average and maximum height of 3 ft. and 4 ft. 7 in. respectively. The seedling is sensitive to drought.

Silvicultural characters. This species belongs to the hygrophilous type of dipterocarps (see p. 32), and its silvicultural characters and conditions of reproduction are somewhat similar to those of *D. turbinatus*.

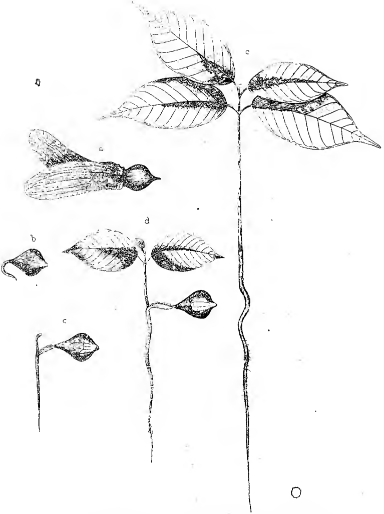

FIG. 10. *Dipterocarpus indicus* (West India). Seedling × $\frac{3}{8}$.
a, fruit; *b*, *c*, germination stages (wings removed from fruit); *d*, seedling one month old; *e*, seedling towards end of first season.

3. **Dipterocarpus obtusifolius,** Teysm. Vern. *Inbo, kanyingôk,* Burm. (Specimens of *inbo* or *kanyingôk* from Thaungyin have been identified as *D. tuberculatus* var. *grandiflorus*).

A large deciduous tree up to 80 ft. high; bark rough, grey, reddish brown inside, longitudinally fissured and slightly transversely cracked. The bole is usually clean, the branches spreading more or less umbrella-like above.

DISTRIBUTION AND HABITAT. Burma, common in the hills east of the Sittang, and in the *indaing* forests of the Prome District (Kurz). Common in Cochin China, Cambodia, and Siam. The tree has habits somewhat similar to those of *D. tuberculatus*, growing gregariously in dry forest which may be termed 'hill *indaing*', up to 3,000 ft. elevation. This forest occurs mainly on laterite or on sandy or gravelly soil overlying metamorphic formations. Here *Dipterocarpus obtusifolius* is associated with various oaks, *Engelhardtia Colebrookiana, Schima bancana, Castanopsis tribuloides, Dillenia aurea,* and occasionally with certain trees of the ordinary *indaing* forest, such as *Dipterocarpus tuberculatus, Shorea obtusa, Pentacme suavis, Melanorrhoea usitata,* and others. *Pinus Merkusii* is sometimes found in this type of forest, while towards its upper limit *P. Khasya* makes its appearance. In this forest there is usually a characteristic growth of grass, rendering it inflammable and liable to fierce fires. Ryan and Kerr,[1] writing of the occurrence of the tree in Siam, say that it commonly forms forests in two situations, on the plain where the soil is sandy, and on steep slopes and crests of ridges at 2,000–3,000 ft. elevation: on the hills this forest is usually on red clay, and *D. obtusifolius* forms about 50–60 per cent. of the crop, most of the other trees being oaks, with occasional *Shorea obtusa* and *Pentacme suavis.*

LEAF-SHEDDING, FLOWERING, AND FRUITING. According to Ryan and Kerr the tree in Siam flowers from November to January, the leaves falling a little later, and the fruit ripens in March–April: the wings are 4–6 in. long. Kurz says the flowering season is March–April and the fruit ripens April–May (Burma). The fruits are heavy, and are probably not carried very far from the tree in spite of the fact that there are fairly strong breezes towards the end of the hot season when they ripen.

SILVICULTURAL CHARACTERS. The tree has the general silvicultural characters of the xerophilous type of dipterocarps (see p. 32). It is adapted by its thick rough bark to withstand the annual fires; the seedlings are burnt back, but a certain proportion eventually establish themselves. As remarked by Ryan and Kerr, an adaptation for withstanding drought in the dry habitat of this species is its capacity for storing water in its tissues: a characteristic of the young tree is that when cut it exudes a quantity of water which drops out freely when the cut stem is held upside down. The tree coppices well, but does not produce root-suckers. It is a light-demander, and regeneration sometimes springs up freely in abandoned *taungyas.*

4. **Dipterocarpus pilosus,** Roxb. Syn. *D. Baudii,* Korth. Vern. *Hollong,* Ass.

A large evergreen tree reaching a height of 100 ft. and exceptionally 120 ft., with a long clean bole. Trees up to 23 ft. in girth have been recorded.

DISTRIBUTION AND HABITAT. Upper Assam, Chittagong, Arakan, and

---

[1] *loc. cit.*

Tenasserim, and the hills east of the Sittang in Burma: found also in Sumatra and the Philippines. It is found in moist evergreen forests, and though very common in places, particularly in Assam, it can hardly be called a gregarious tree in India or Burma. In Sumatra and the Philippines it is said to be gregarious. It grows on moist well-drained ground, both on flat land and on low hills. In its natural habitat the absolute maximum shade temperature varies from 98° to 102° F., the absolute minimum from 40° to 50° F., and the normal rainfall from 90 to over 200 in.

Fruiting. In Assam the fruits, which are heavy, with wings 7–9 in. long, ripen in February and March, after which there is usually much wet weather until the rainy season commences.

Silvicultural characters. The main silvicultural characters are those of the hygrophilous type of dipterocarps (see p. 32), but these characters have not yet been studied in detail for this species. Fires seldom if ever occur in the type of forest in which it is found. Mr. Kanjilal informs me that in Assam natural reproduction is profuse where the rainfall approaches or exceeds 100 in. He also notes that seedlings endure shade until they reach the sapling stage; from then onwards an increasing amount of light is required, and mature trees have their heads well above the surrounding leaf-canopy.

5. **Dipterocarpus tuberculatus**, Roxb. Syn. *D. grandiflorus*, Wall. Vern. *In*, Burm.; usually known in English as 'eng'. Specimens of *inbo* or *kanyin-gôk* from Thaungyin have been identified as *Dipterocarpus tuberculatus*, Roxb., var. *grandiflorus*.

A large resinous tree, deciduous or nearly so, with a straight clean cylindrical bole and stout branches. Bark dark grey, brown inside, thick, rough, and longitudinally furrowed. Wood reddish brown, hard, moderately durable, largely used in Burma for building and occasionally exported to Europe. In favourable localities the tree attains a height of 80 to 100 ft., with a clear bole of 50 to 60 ft. and a girth of 8 to 10 ft.; exceptionally it may attain a height of 120 ft. or more and a girth of 15 ft. The following measurements of large trees have actually been recorded:

(1)	Height 120 ft.:	clear bole 54 ft.:	girth 12 ft.	(F. J. Branthwaite, Toungoo).
(2)	,, 100 ft.:		,, 15 ft.	(F. J. Branthwaite. Toungoo).
(3)		,, ,, 95½ ft.:	,, 9 ft. 4 in.	(C. B. Smales, Pyinmana).
(4)	,, 130 ft.:		,, 8 ft. 6 in.	(R. M. Kavanagh, Shwebo).
(5)	,, 130 ft.:	,, ,, 80 ft.:	,, 9 ft. 9 in.	(R. S. Troup, Katha).
(6)		,, ,, 75 ft.:	,, 11 ft. 1 in.	,, ,, ,,

Distribution and habitat. The *in* tree, which grows gregariously in a special type of deciduous forest known as *indaing*, described below, is found throughout Burma, in suitable localities, up to about 2,500 ft. and occasionally over, from the Myitkyina and Upper Chindwin districts in the north to the Mergui district in the south: it occurs in the Northern and Southern Shan States and extends eastward into Cambodia and Siam. The largest tracts of *indaing* forest occur between the Irrawaddy and Chindwin rivers in Upper Burma, where they aggregate several thousand square miles. In the Chindwin drainage *indaing* is not common north of Homalin, while west of the river it is less common in the Upper Chindwin district than farther down in the Myittha neighbourhood. East of the upper Irrawaddy there are considerable tracts of *indaing*, varying in size, from the Myitkyina district in the north to the Mandalay district in the south. In the Pegu Yoma *indaing* forest is found to a greater or less extent flanking the outskirts of the teak forests both on the east and on the west side; this type of forest also extends a considerable distance into the hills. *Indaing* is found in the dry zone of Upper Burma, though the trees do not attain large dimensions there. East of the Sittang river a belt of *indaing* runs almost continuously along the base of the hills forming the Sittang-Salween watershed from the Yamethin district southward to some distance below Shwegyin. West of the Irrawaddy below Mandalay it occurs in stretches of varying size from the Pakokku district southward to the Bassein district, ascending the Arakan hills to about 2,500 ft. On the Arakan side the *in* tree is said to be found in the Kyaukpyu subdivision on hill-sides up to 1,200 ft. in groups in evergreen forest with an undergrowth of palms and canes, which is quite unlike its ordinary habit. Its distribution in Chittagong has not been determined. In the lower Salween, Thaungyin, and Ataran drainages *indaing* forest is found scattered in patches of varying extent; these continue southward to the Tavoy and Mergui districts.

In *indaing* forest the *in* tree is usually the most prevalent species and is commonly associated with *Pentacme suavis*, *Shorea obtusa*, *Melanorrhoea usitata*, *Buchanania latifolia*, *Diospyros burmanica*, *Aporosa macrophylla*, *Dillenia pulcherrima*, *Careya arborea*, *Dalbergia cultrata*, *Terminalia tomentosa* var. *macrocarpa*, a stunted form of *Xylia dolabriformis*, and others, while in Upper Burma occur *Dalbergia Oliveri* and certain oaks. Teak of small size is sometimes found scattered in *indaing* forest. Among small trees may be mentioned *Gardenia erythroclada*, *G. coronaria*, *G. sessiliflora*, *G. turgida*, *G. obtusifolia*, *Randia dumetorum*, *Strychnos Nux-blanda*, and *Wendlandia tinctoria*.

Indaing forest varies greatly in quality. It is found most commonly on laterite, often with a red clay soil; here *in* is usually the prevailing tree, reaching a large size in places where the overlying soil becomes a deep sandy loam. *Indaing* forest containing large-sized *in* is also found on almost pure sand. On hard ferruginous laterite with siliceous pebbles, where the soil is shallow, the forest becomes very open and poor in quality. A type of *indaing* occurs on stiff clay soils, but in such places *Terminalia tomentosa* var. *macrocarpa* tends to become the predominating species, and *in* may be entirely absent; this type is exemplified near Teinhmyôk in the Tharrawaddy district and elsewhere. In the plains of the Hanthawaddy district *in* forest tends to merge into lower mixed forest. The best *indaing* forest is found on flat or slightly undulating land, always on porous well-drained soil above the reach of floods. On dry hills and ridges it is frequently stunted and tends to develop into a type containing little or no *in*, but much *ingyin* (*Pentacme suavis*) and *thitya* (*Shorea obtusa*). In the upper mixed teak forests of the Pegu Yoma and elsewhere *in* is often found occupying the tops of ridges, sometimes accompanied by teak of small size. In the Myingyan district on the flat and undulating land immediately to the east of Popa Mountain there is a patch of forest on volcanic ash consisting of *in* partly pure and partly mixed with teak. In some parts of Upper Burma forest of a somewhat moist type is occasionally found, in which *in* is mixed with *kanyin* (*D. turbinatus*); here the trees reach very large dimensions. In the Chindwin an occasional type is met with on dry sandy loam consisting chiefly of large *in* trees with a lower story of oaks (chiefly *Quercus spicata*). The *indaing* forests of the hill ranges extend into the region of pines (*Pinus Khasya* and *P. Merkusii*), but in these forests the *in* is often replaced by *inbo* (*D. obtusifolius*).

The soil-covering in *indaing* forest varies considerably. In the dry stunted open types with shallow soil there is often little or nothing growing on the bare laterite rock or dry gravel except occasional scanty tufts of grass. The soil-covering in the usual type of *indaing* on more or less level ground often consists of extensive stretches of grass, through which severe fires rage in the dry season (see Fig. 11). The grasses in *indaing* forest are well worth special study in connexion with the silviculture of the tree, as in the case of those of the sal forests of India. There is sometimes a shrubby undergrowth present which increases with the fertility of the soil; this, however, is not of the dense character found in evergreen forest, and usually consists mainly of a rather sparse low growth of *Indigofera*, *Flemingia*, *Desmodium*, *Strobilanthes*, *Inula Cappa* and *polygonata*, *Bauhinia acuminata*, *Thespesia Lampas*, *Barleria cristata* and other shrubs, while *Cycas siamensis* and *Phoenix acaulis* are often very common. Bamboos are usually scarce or absent; where present the most characteristic species are *Dendrocalamus strictus*, *Bambusa Tulda*, and *Oxytenanthera albociliata*: other species also occur at times, but they are less characteristic. Climbers are by no means plentiful, but a feature of these open forests is the number of epiphytic orchids met with. Many herbaceous plants, chiefly perennials with tuberous roots, spring up in the rainy season and flower towards the end of the rains or in the cold season. Most of the trees are leafless during part of the hot season, but many of them flower at this time, and the bright colours and the perfume compensate to some extent for the lack of foliage, while on the ground blackened by the jungle fires, bright-coloured flowers spring up, chiefly those of monocotyledonous plants (Scitamineae and Amaryllidae). The orchids flower for the most part in the hot season, adding to the general colour effect: at this season such attractions are by no means without their value in these hot and often waterless tracts, where the woes of the traveller are not lessened by the incessant noise of countless cicadas which choose this time of year to assert themselves, particularly in *indaing* forest.

Indaing furnishes an interesting example of a type of forest the occurrence of which is determined mainly by geological formation, and to some extent by the configuration of the ground as affecting the degree of moisture in the soil. Thus in Burma, as surely as laterite is met with, so surely, with very few exceptions, will this type of forest occupy the ground. Again, this type—in which, however, *in* is often replaced entirely by *Pentacme suavis* and *Shorea obtusa*—frequently occurs along dry ridges, the lower slopes of which are occupied by mixed deciduous or evergreen forest. The component species of *indaing* forest are adapted to withstand a degree of dryness in the soil which most species in the same climatic region would be incapable of enduring.

As regards climatic requirements, *indaing* forest occurs throughout Burma in localities where the absolute maximum shade temperature varies from 100° to 110° F., the absolute minimum from 40° to 50° F., and the normal rainfall from 35 to 120 in. or possibly more, though the *in* tree itself does not occur except in stunted form where the rainfall is less than 40 in. Although the *in* is characteristically found on dry porous formations, there is a limit to the degree of dryness which it will stand. The most arid portions of the dry zone of Upper Burma are occupied by scrub forests of *Acacia Catechu*, *A. leucophloea*, and other xerophilous species, and where *in* occurs it is not found in the driest regions. A form of poor stunted *indaing*, it is true, occurs in certain portions of the dry zone, but the predominating dipterocarp is usually *Pentacme suavis*, sometimes associated with *Shorea obtusa*; these two species appear to stand a greater degree of dryness than *in*.

The relative proportion of *in* to other *indaing* species varies according to the type of forest; in some types it predominates largely, while in others it is to a great extent, if not entirely, replaced by *Pentacme suavis* and *Shorea obtusa*. Various enumerations have been made in sample plots of *indaing* in which *in* predominates. The maximum number of *in* trees 3 ft. and over in girth recorded is an average of 24 per acre in a sample plot of 86·6 acres in the Gwethe reserve, Toungoo. A few plots containing 20 and over, and many containing 15 and over per acre, have been recorded in sample plots varying from 40 to 200 acres in area. The highest percentage of *in* trees in the growing stock is recorded in a sample plot of 114 acres in the Gwethe reserve, where *in* forms 83 per cent. of the crop of trees 3 ft. and over in girth: it is exceptional to find it constituting more than 70 per cent. of the growing stock.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The large stiff shiny leaves, up to 1½ ft. long, or more in vigorous saplings and coppice-shoots, are shed in the hot season about March, and the new leaves appear at once, or even before the old ones have all fallen, the large stipules, 4–5 in. long, falling as the young leaves expand. The rose-coloured flowers appear in March–April; the fruits, whose wings are 5–6 in. long, ripen in May, and are dispersed by the strong winds which are usually prevalent at this time. Records of seed-years are somewhat scanty, but such as they are they show that occasional poor seed-years occur; otherwise it is known that the tree produces a good crop of seed in most years.

SILVICULTURAL CHARACTERS. The *in* tree is a decided light-demander, as shown by the open character of the forest in which it grows, the readiness with which it responds to openings in the canopy, and its intolerance of suppression. It resists the effects of fire to a remarkable degree, seedlings and saplings which are burnt back showing great power of recovery from the base and sending up stout stems, while the thick rough bark forms an efficient protection to the growing tissues underneath. Its capacity for thriving on porous geological formations and soils which have a low percentage of moisture has already been alluded to. Frost does not occur within its habitat except possibly near its upper limit, where, however, no frost damage has ever been recorded.

Young trees coppice well, but larger trees as a rule fail to coppice. Root-suckers, if they occur at all, are not a usual means of reproduction; Ryan and Kerr state that they have noticed them very occasionally in Siam. As in other dipterocarps, new growth starts in the hot season when the new leaves appear, and most of the season's growth is put on during the first month or two, although growth continues to some extent during the rains.

NATURAL REPRODUCTION. The fruit falls after the season of fires, and is therefore not exposed to the risk of destruction from this source. The seed germinates immediately after it falls, and when the rains break about the middle of May, the seedlings have a favourable start. Lack of rain, however, may cause failure of the seedling crop, particularly in dry localities; thus experimental sowings in the Minbu division in 1907 resulted in failure, the seed germinating successfully but the seedlings nearly all dying for want of rain in June. Given suitable conditions the seedlings come up in enormous quantities, and the profusion with which natural reproduction of *in* takes possession of the ground is one of the remarkable characteristics of this tree: this is well illustrated in Fig. 12. It is only where the crop is sufficiently open that natural reproduction establishes itself in profusion. Many of the more accessible *indaing* forests of Burma, which have been heavily overworked, contain dense crops of poles and saplings, the result of the free admission of light; these are often partly of coppice origin, though seedling reproduction plays a prominent part. The seedlings in their earlier stages are usually burnt back by the annual fires, but thanks to a thick well-developed root, great power of recovery from the base, and a stout stem well protected by rough bark, they eventually establish themselves.

Under certain conditions, however, reproduction fails to establish itself, as in the case of very poor localities where the forest is open and the trees stunted, with bare rock coming to the surface or at most a shallow covering of loose gravelly soil. Here the absence of reproduction is no doubt due partly to the fact that seed is washed away in the rains, or if it remains and germinates the roots cannot obtain a foothold, and partly to the fact that any seedlings which do spring up are killed off by drought, since the root-system cannot develop. Cases of this kind, however, are of little consequence, since even if regeneration were obtained the resulting forest would be so poor as to be of little value. There is, on the other hand, another type of *indaing* where the scarcity or absence of reproduction gives cause for anxiety. This is the type consisting of a rather open crop of *in* trees, often of large size and excellent quality, where the ground is usually covered with a plentiful growth of coarse grasses, with or without shrubs, but where reproduction fails to appear even if there is sufficient light (Fig. 11). The natural reproduction of the *in* tree has not yet been studied in sufficient detail to explain this phenomenon by the results of direct experiment, but the striking similarity which the reproduction of this tree bears in some respects to that of the sal (*Shorea robusta*), which has been studied in greater detail, may furnish a possible explanation of it. Assuming that light conditions are suitable, as they frequently are, a possible cause of failure of reproduction, where a heavy growth of grass is present, is fire; it is known, however, that in many places *in* reproduction

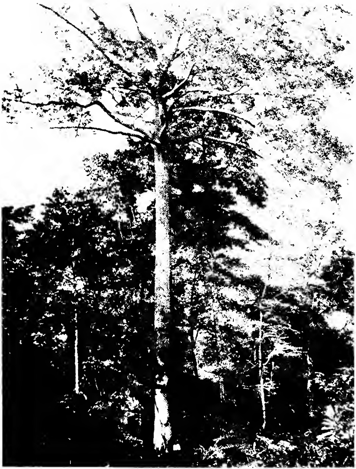

FIG. 13 *Dipterocarpus alatus*. 18 ft. in girth. Magayi reserve. Insein forest division, Burma

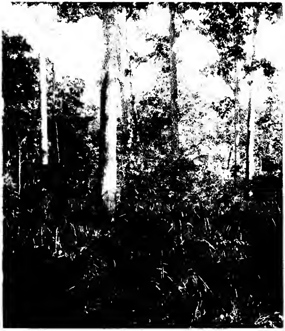

FIG. 11. *Dipterocarpus tuberculatus*, large trees in open forest with soil covering of coarse grass. Katha, Upper Burma. Note man at base of near tree.

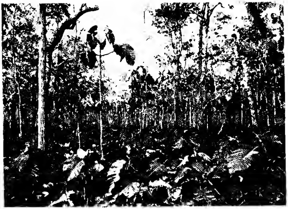

FIG. 12. [illegible]

establishes itself in burnt areas in spite of the presence of grass, so that although fire may be a contributory cause it is not the sole, and possibly not even the chief, cause of failure. It is more probable that unfavourable soil conditions, expressed by the term bad soil-aeration, are the primary cause; the remarks on this subject in respect of sal seedlings (pp. 84–86) may help to throw some light on the question. If this is in reality the primary cause, then it may be possible, as in the case of the sal, to stimulate reproduction by hoeing the soil thoroughly and, if necessary, sowing freshly collected seed.

Observations regarding the effect of fire-protection on the regeneration of *indaing* forest have not yet revealed any definite results. The tree regenerates so freely in annually burnt areas that under ordinary conditions expenditure on fire-protection, except possibly during the early stages in the establishment of the young crop, seems hardly justified in the absence of very marked beneficial effects on the establishment of reproduction or the development of the crop. Annual fires do not damage the timber to any extent except in the case of trees tapped for wood-oil, and this custom is not permitted where regulated working is in force.

If the analogy between *in* forest and sal forest holds good, then fire-protection is likely to have an adverse effect on the germination of the seed and the establishment of the seedling owing to the layer of dead leaves on the ground. In the case of the sal it has been proved by experiment that seed falling on a thick layer of dead leaves may entirely fail to germinate if exposed to the sun, while under shelter, although the seed germinates and the seedlings develop during the first rainy season, their roots fail to reach the mineral soil, and the seedlings die off during the ensuing dry weather. If this happens in the case of the sal it may be expected to be even more pronounced in the case of the *in*, whose leaves are much larger and stiffer. In fire-protected *in* forests, therefore, the burning of the accumulated dead leaves in good seed-years, before the fall of the fruits, may be found to be a necessary measure for securing reproduction. An instance of the beneficial effects of burning combined with the admission of light is recorded in the Burma Forest Report for 1914–15: plentiful reproduction is said to have sprung up in the Yetkanzin reserve, North Toungoo, as the result of burning an area in which bamboos had flowered and which had previously been fire-protected for many years.

SILVICULTURAL TREATMENT. *Indaing* forest is well adapted for concentrated regeneration with the view of producing a succession of even-aged crops. This treatment has recently been introduced in Mr. A. P. Davis's working plan for the Indaung working circle.[1] A rotation of 120 years has been adopted tentatively and divided into four regeneration periods of thirty years each. In the first periodic block the number and frequency of the regeneration fellings are not fixed, but a maximum of three fellings is laid down: often only a single final felling will be necessary, since natural reproduction of *in* is plentiful. Blocks not under regeneration will be treated under selection fellings with a minimum girth limit of 8 ft. for sound trees.

RATE OF GROWTH. Accurate figures based on sample plot measurements are not yet available. In the Rangoon Plains working plan (J. J. Rorie) it is estimated from ring-countings that the relative rates of **growth in girth of** *in* and teak in that locality are as follows:

---

[1] Working Plan for the Indaung Working Circle, Ruby Mines Division, 1918.

Girth		1½ ft.	3 ft.	4½ ft.	6 ft.
Age (years)	*In*	27	52	80	112
	Teak	43	67	91	125

Ten years were added in either case to allow for the establishment of the seedling.

It is doubtful, however, if great reliance can be placed on ring-countings on *in* stumps, as the rings are not usually clear.

6. **Dipterocarpus alatus**, Roxb. Vern. *Kanyin*, *kanyin-byu*, Burm.; *Gurjun*, Beng. (Andamans).

A lofty evergreen tree, reaching a height of 150–180 ft. and a girth of 15 ft. or more, with a long clean cylindrical bole and an elevated crown. Bark light grey, pale yellow inside, smooth, fairly thin. Fig. 13 shows a tree 18 ft. in girth: Mr. J. J. Rorie has recorded one 22 ft. in girth.

DISTRIBUTION AND HABITAT. Evergreen and moist forests of Burma, Siam, Cambodia, Cocos islands (Prain), and the Andamans. This tree resembles *D. turbinatus* in general appearance and is associated with it in similar types of forest (see under *D. turbinatus*). In Burma these two species are often referred to together as *kanyin*, and as a rule are not carefully distinguished by foresters. Apart from its frequent occurrence in evergreen types of forest, it is probably the species most commonly found on the plains of Burma in the moister types of lower mixed forest, partly evergreen and partly deciduous, on fertile alluvial ground; here it is associated with *Eugenia Jambolana*, *Lagerstroemia Flos-Reginae*, *L. tomentosa*, *L. macrocarpa*, *Stephegyne diversifolia*, *Adina sessilifolia*, *Careya arborea*, *Mangifera indica*, *Berrya Ammonilla*, and others; occasionally teak of large dimensions is found growing with it. In this type of forest the *kanyin* occupies the moister and richer localities on well-drained ground which, however, is sometimes flooded in the rains. In the evergreen and moist semi-evergreen types of forest on flat to undulating ground or low hills flanking the Pegu Yoma range it is extremely common in places. The smooth light grey cylindrical boles, sometimes well over 100 ft. in length without a branch, are very characteristic, and the crowns tower above the surrounding forest.

In its natural habitat the absolute maximum shade temperature varies from 98° to 105° F., and the absolute minimum from 45° to 60° F., the normal rainfall varying from 60 to over 200 in.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The old leaves are shed early in the hot season. The white flowers appear in February–March and the fruits ripen in May–June: the wings are 5–6 in. long.

SILVICULTURAL CHARACTERS. The main silvicultural characters of this tree are those of the hygrophilous type of dipterocarps (see p. 32), and resemble those of *D. turbinatus*.

RATE OF GROWTH. Accurate statistics determining the rate of growth are not yet available. Ring-countings on stumps in the Rangoon plains forests by Mr. J. J. Rorie showed the following relative rates of growth of *kanyin*, in (*Dipterocarpus tuberculatus*), and teak:

Girth		1½ ft.	3 ft.	4½ ft.	6 ft.
Age (years)	*Kanyin*	35	55	79	105
	In	27	52	80	112
	Teak	43	67	91	125

Ten years were added in each case to allow for the establishment of the seedling. It is doubtful, however, if great reliance can be placed on the figures for the dipterocarps, as the rings are not always conspicuous.

2. HOPEA, Roxb.

Evergreen trees of the moist tropical forests.

Species 1. *H. odorata*, Roxb.; 2. *H. parviflora*, Bedd.; 3. *H. Wightiana*, Wall.

1. **Hopea odorata**, Roxb. Vern. *Thingan*, Burm.

A large evergreen tree reaching a height of 100–120 ft. and a girth of 12 ft. or more, with a long clean cylindrical bole. Bark grey to dark brown, longitudinally furrowed, yellow or reddish inside. This is the most valuable of the Burmese dipterocarps, having a hard very durable timber much in request for boat-building, canoes, and construction generally.

DISTRIBUTION AND HABITAT. Burma, from Pyinmana southwards through Pegu and Tenasserim, and in the Andamans. It extends into Siam and Cochin China. In Burma it occurs sporadically in moist tropical forests, where it is common in Tenasserim and in parts of Pegu, both to the east of the Sittang and in the moister forests of the eastern drainage of the Pegu Yoma, extending northwards into the damper ravines of the Pyinmana forests in Upper Burma: on the western side of the Pegu Yoma it extends as far north as the Tharrawaddy district, and though it has occasionally been recorded as far north as the Thayetmyo district, it is extremely rare. Its chief associates are *Dipterocarpus turbinatus* and *alatus*, *Sterculia alata*, *Tetrameles nudiflora*, *Artocarpus Chaplasha* and *Lakoocha*, *Swintonia Schwenckii*, *Garcinia* spp., and other trees characteristic of moist tropical forest: the undergrowth is usually of a dense evergreen character, with various palms and canes and masses of climbers. *Hopea* is found typically on deep rich soil, most commonly along the banks of streams and in damp situations. In the Andamans it is found scattered in moist tropical evergreen forests associated with *Dipterocarpus turbinatus*, *D. Griffithii*, and other species, *Calophyllum spectabile*, *Mimusops Elengi*, *Artocarpus* spp., and many other trees, with a dense undergrowth of the climbing bamboo *Dinochloa andamanica*, various canes, and many climbers.

In its natural habitat the absolute maximum shade temperature varies from 98° to 105° F., and the absolute minimum from 45° to 60° F., the rainfall varying from 90 to over 200 in.

FLOWERING AND FRUITING. The small white fragrant flowers appear in March and April and the fruits ripen in May and June: the latter are small, the two wings being about 1·5 in. long. As in all the dipterocarps, the fruits germinate as soon as they fall.

SILVICULTURAL CHARACTERS. This tree is one of the most hygrophilous of all the dipterocarps, and its general silvicultural characters are those of the hygrophilous or sporadic type (see p. 32). It stands a considerable amount of shade, particularly in youth.

2. **Hopea parviflora,** Bedd. Vern. *Kongu, vellai kongu*, Tam. ; *Bovumara, kiralboghi, tirpu*, Kan. ; *Thambagam, kambagam*, Mal., Trav. ; *Iruppu*, Coorg. Ironwood of Malabar. White kongu (Tinnevelly).

A very large handsome evergreen tree with a dense crown, conical in youth, reaching a height of 120 ft. and a girth of 15 to 18 ft. and exceptionally more, and producing a straight clean cylindrical bole 60 to 80 ft. long. Bark light brown or greyish mottled with white markings, smooth in young trees, somewhat rougher and rusty brown in older ones. Leaves bright green, about 2–4 in. long. The wood is a valuable one, hard, heavy, and durable, used for building and boats. Mr. P. M. Lushington records a case of a large tree felled in the Tinnevelly district which is said to have produced over 200 rafters of nearly 2 cubic ft. each.

DISTRIBUTION AND HABITAT. Coorg, up to 2,500 ft., South Canara, Malabar, Travancore, and Tinnevelly, in moist tropical evergreen forest. Foulkes says that it prefers rich deep moist soil, growing best on river-banks and in moist valleys, but will thrive even on dry hard laterite, which it prefers to gneiss. Mr. P. M. Lushington,[1] writing of the tree in Tinnevelly, says he has seen it in several places growing with or close to *Pterocarpus Marsupium* in the moister parts of the higher deciduous forests, but that more frequently it grows with *Pterospermum* spp., *Vitex altissima*, *Diospyros* spp., and *Filicium decipiens*: he says that there are often patches of nearly pure *Hopea* forest, and that it is a tree which is nearly always found in large patches. In Tinnevelly its area is decidedly limited, but regeneration is said to be good, and there appears to be no likelihood of its diminution. In this district *Hopea parviflora* is known as *Vellai kongu* or white kongu, and *Balanocarpus utilis* as *karin kongu* or black kongu, and on the occurrence of these two trees Mr. Lushington remarks: 'The lowest elevation at which I have found kongu is just below 1,000 ft. . . . and the highest . . . 2,800 ft. The lowest were the black variety and the highest the white: but between these two elevations both kinds are found very commonly growing together. It is essentially a semi-shola tree, and seems to prefer a rich soil, but I have found well-grown saplings growing out of the crevices of slab rock on the banks of the Servi Ar and Kudivarai Ar, and both species seem able to support themselves in such situations. One fact in connexion with kongu has particularly struck me—it is found mainly on the hill-sides bordering on large rivers, and even when a little distance away from the river it is invariably on the bank of a ravine. The close proximity of running water appears to be essential to its growth.'

Bourdillon[2] says that it is abundant and gregarious in the interior forests of Travancore which have not yet been worked, especially from 1,000 to 2,000 ft.; at lower elevations it is less gregarious, and is found chiefly along river-banks. Writing in the *Indian Forester*,[3] he says it is found in most of the evergreen forests between sea-level and 3,000 ft., and at all elevations it is found scattered through the forest, often in groups. 'In the low country', he adds, 'it is generally to be seen on river-sides, but this is because it has been cleared away from the adjacent land, for where groves or patches of forest have been left this tree is found in them, even far from water. At the same time it is a tree that likes moisture, for it thrives in swampy patches where other trees would die.'

---

[1] Ind. Forester, xxix (1903), p. 431.

[2] Forest Trees of Travancore.

[3] Ind. Forester, xxx (1904), p. 18.

In its natural habitat the absolute maximum shade temperature varies from 95° to 100° F., the absolute minimum from 60° to 65° F., and the normal rainfall from 35 to over 150 in.

Flowering and fruiting. The small cream-coloured fragrant flowers, in grey-tomentose panicles, appear in January and February, and the fruit ripens in May and June. The light fruit (Fig. 14, *a*) has two straw-coloured wings less than 2 in. long, the nut being 0·25 in. long; it is thus capable of being blown to a considerable distance. As in other dipterocarps the seed germinates soon after reaching the ground, and quickly loses its germinative power. The tree seeds freely at frequent intervals.

Germination (Fig. 14, *b–d*). Epigeous. The shell of the nut cracks and the radicle emerges from near its apex, curving downwards and rapidly forming a taproot. Meanwhile the elongation of the hypocotyl withdraws from the fruit the fleshy cotyledons, which expand and are carried above ground, the young shoot appearing from between them.

The seedling (Fig. 14).

Roots: primary root moderately long and thick, terete, tapering, woody: lateral roots moderate in number or numerous, short to long, fibrous, distributed down the main root. *Hypocotyl* distinct from the root, 0·8–1·5 in. long, terete, slightly fusiform, minutely tomentose. *Cotyledons*: petiole 0·15 in. long, thick, somewhat flattened, minutely pubescent: lamina divided nearly to the base into two thick fleshy angular lobes 0·25–0·4 in. long. *Stem* erect, terete, woody, young parts minutely tomentose. Internodes, first (between cotyledons and first foliage leaves) 1·5–2·5 in. long, subsequent internodes 0·1–1·3 in. long. *Leaves*, first pair opposite, subsequent leaves alternate. Stipules 0·05–0·1 in. long, narrow triangular acuminate, tomentose, caducous. Petiole 0·1–0·15 in. long, minutely tomentose. Lamina, first pair 1·2–1·9 in. by 0·35–0·6 in., subsequent leaves 0·7–2·7 by 0·25–0·9 in. long, ovate lanceolate, acute or acuminate, base rounded or acute, entire, glabrous, but midrib on under surface of young leaves minutely pubescent and margins sometimes with a fringe of minute hairs; lateral veins 6–12 pairs.

Seedlings ordinarily attain a height of 3–8 in., with 6–12 leaves, by the end of the first season. In Coorg young plants four years old attained an average and maximum height of 1 ft. 10 in. and 3 ft. 2 in.

Silvicultural characters. The main silvicultural characters are those of the hygrophilous type of dipterocarps (see p. 32). Foulkes says it has a long deep taproot with few lateral roots: this would enable it to grow on comparatively dry situations, as it appears to do at times, the root penetrating to moister strata below. He adds that it is a strong shade-bearer, but that light requires to be admitted in the case of saplings more than three years old. Bourdillon says that poles are not often seen in dense forest, as they cannot bear very heavy shade. The tree is more light-demanding than *Balanocarpus*, with which it is associated in Tinnevelly.

Natural reproduction. The tree regenerates naturally with freedom in South Canara. Foulkes remarks that it does so better than any other species except *Xylia*. Bourdillon says that seedlings may be found under the parent

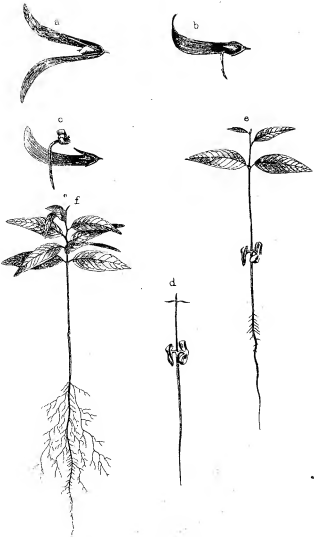

FIG. 14. *Hopea parviflora.* Seedling × $\frac{5}{8}$.

a, fruit; *b–d*, germination stages (near large wing removed in *b* and *c*); *e*, seedling one month old; *f*, seedling five months old.

trees in vast numbers, but that they cannot establish themselves under heavy shade; he adds that young trees are often seen springing up on land that has been cleared by hillmen and abandoned, and also on abandoned coffee estates under the shade of bushes and small trees. The light winged seed is adapted for regeneration on open spaces of this kind. Cleanings have been found to be beneficial to the establishment of natural reproduction.

Experiments carried out by Mr. H. Tireman in Coorg in recent years indicate that the seedlings require protection from the sun only in the first year or two, after which the removal of the cover greatly stimulates growth and assists in the establishment of reproduction, which often appears in dense masses, particularly in small clearings.

Hopea parviflora sometimes regenerates freely in the more open teak plantations of Malabar, forming an underwood to the teak (see Fig. 15).

As regards the effect of cutting *Strobilanthes* on the natural reproduction of this tree, Forest Ranger C. P. Garudachellam [1] notes that in the South Canara district over an experimental area of 5 acres covered with *Hopea* seedlings *Strobilanthes* was cut during 1913–14, and that an inspection after the heavy monsoon rains showed that this greatly stimulated the development of the *Hopea* seedlings.

ARTIFICIAL REPRODUCTION. In South Canara crops have been raised successfully by broadcast sowings in moist situations or under moderate shade; these sowings have proved cheaper and more successful than transplanting seedlings, an operation which requires a good deal of care. Overhead cover requires to be removed after two or three years. Bourdillon says that in Travancore artificial propagation has not been attended with success: seeds sown in nursery beds do not readily germinate, and the plants which are produced are sickly. He adds that plants collected from the forest and planted out fail in large numbers, probably owing to their long taproots having been broken in moving them.

SILVICULTURAL TREATMENT. Mr. P. M. Lushington, writing of the treatment of *Hopea* (white kongu) and *Balanocarpus* (black kongu) in Tinnevelly, says: 'The difference in the leaf and the nature of the seed must entail considerable differences in the silviculture of the two species. The black kongu, with its large and heavier leaf, is more of a shade-lover than the white variety. The difference in the seed is evidently due to the same cause. The lightness of the white kongu seed, with its attached wings, causes it to spread over a much larger distance and to settle in places where there is plenty of light. The heavy seed of the black kongu falls directly to the ground, and under the shade of the parent tree hundreds of young seedlings readily spring up. A mixed forest of the two kinds of kongu would be similar to the mixture of oak and beech in Europe, and in order to favour white kongu there must be larger clearance overhead. There should be no difficulty, therefore, in raising pure forests of the two species, taking precautions that the white variety is not suppressed. As the white variety springs up more quickly when a clearance is made, it should get a start of the black which will be favourable to both species. As a result it appears that a treatment of regular high forest with thinnings should be particularly applicable, and the more the two trees can be induced to grow in unison the better should be the results. This seems to be the ideal to be aimed at, but will take many years to carry out.'

---

[1] Ind. Forester, xlii (1916), p. 247.

He proposes to carry out this treatment by a gradual opening of the canopy by girdling inferior species in order to free existing advance growth and to induce further regeneration where kongu seed-bearers are present: this opening would be more drastic round white than round black kongu seed-bearers.

This treatment is somewhat similar to that advocated for *Dipterocarpus turbinatus* in Burma: as in the case of this species, so in the case of *Hopea* and *Balanocarpus*, the use of fire for preparing the ground will no doubt stimulate regeneration where it can be applied. This treatment is one which may be considered to be generally applicable to dipterocarps of the hygrophilous type.

RATE OF GROWTH. The rate of growth cannot be ascertained from ring-countings, as there are no annual rings in the wood. Bourdillon states that the best of a group of trees planted in Travancore measured 61 ft. in height and 7 in. in diameter at breast-height in ten years, and a tree fifteen years old was 9 in. in diameter, though it had been retarded in growth by the cutting of some of its roots. He also quotes the following measurements of a tree planted in the forest bungalow compound at Malayattur in Travancore in 1888:

Age.	Height.	Girth.
Years.	ft.	in.
10	26	18
11	—	20¼
12	47	23½
14	—	27½

Taking the measurements at twelve years, a mean annual girth increment of about 2 in. and a mean annual height increment of about 4 ft. are obtained: this is rapid growth, though the conditions may have been exceptionally favourable. Bourdillon considers from personal observation that the tree grows slowly for the first six years of its existence, and after that more rapidly. Mr. Lushington considers that no tree should be felled until it is 8 ft. in girth. Very large trees are often unsound.

3. **Hopea Wightiana**, Wall. Vern. *Haiga, hiral bogi*, Kan.; *Kavsi*, Mar.; *Ila pongu*, Tam.

A large tree with a stout stem. Bark thin, smooth, exfoliating in large rectangular plates, white or yellowish inside. Wood hard and heavy, much used for building.

As this tree is sometimes associated with *H. parviflora*, Bourdillon's key to the two species may be quoted:

Leaves 3½ in. by 1½ in., petiole ⅓in., panicles grey-tomentose, flowers ⅙ in. across, cream-coloured, wings of the fruit straw-coloured, under 2 in. long . . . *H. parviflora*.

Leaves 5–8 in. by 2–3 in., petiole ½ in., panicles glabrous, flowers ⅓ in. across (Talbot says 0·5 in.), yellow tinged with red, wings of the fruit red, 2–3 in. long . . . *H. Wightiana*.

Round echinate galls are often found in the axils of the leaves.

DISTRIBUTION AND HABITAT. Evergreen forests of the Western Peninsula

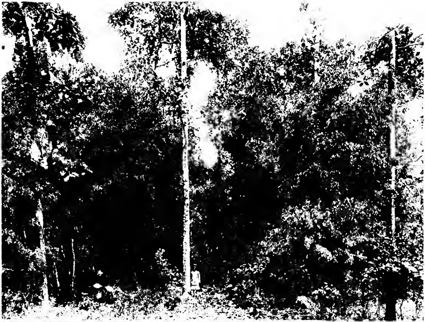

Fig. 45. Teak plantation with natural underwood of *Hopea parviflora*, South Malabar.

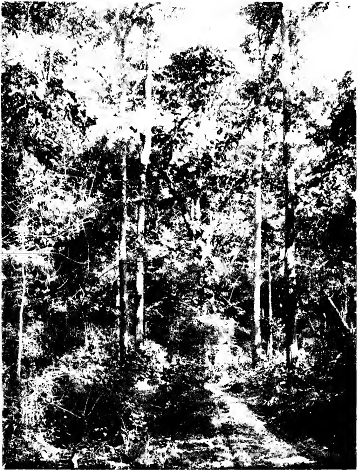

FIG. 16. *Pentacme suavis* in semi-*indaing* forest of good quality, Mongnai State, Upper Burma.

from the Konkan southwards to Tinnevelly: often gregarious along river-banks and in the low coast country. Bourdillon says that in Travancore it is much less common than *H. parviflora*, and as far as he has observed, is confined to the lower elevations: in former times, when evergreen forests spread all over the low country, it was doubtless common enough, but at present only a few trees are met with in groves or on the sides of rivers. In its natural habitat the absolute maximum shade temperature varies from 95° to 100° F., and the absolute minimum from 60° to 65° F., the normal rainfall varying from 35 to over 150 in.

Flowering and fruiting. The flowers, which are yellow or white tinged with red, appear in March and April, and the fruits ripen in May and June; the wings are 2–3 in. long by ½ in. wide, bright crimson, and the trees are very handsome when covered with the crimson fruits towards the end of the hot season. As in other dipterocarps, the seed germinates soon after reaching the ground.

Silvicultural characters and treatment. The main silvicultural characters are those of the hygrophilous type of dipterocarps (see p. 32). Beddome says that *H. Wightiana* var. *glabra* (*H. glabra*, W. and A.) coppices well. As far as is known the silvicultural treatment proposed for *H. parviflora* would be equally applicable to this species.

3. PENTACME, A. DC.

Pentacme suavis, A. DC. Syn. *P. siamensis*, Kurz; *Shorea siamensis*, Miq. Vern. *Ingyin*, Burm.

A large deciduous, usually gregarious tree, reaching a height of 80 ft. or more and a girth of 10 ft. or over; Mr. A. Rodger records one of 16 ft. in the Ruby Mines district. Bark thick, rough with deep vertical fissures and with transverse cracks, dark grey, reddish brown inside. Wood very hard and durable, much in demand for building purposes. Lac is sometimes produced on this tree.

Distribution and habitat. Throughout Burma, in *indaing* and in dry deciduous forest. It extends to a good many localities where *Dipterocarpus tuberculatus* is absent or comparatively rare, as in parts of the dry zone of Upper Burma and on many dry ridges throughout the country. In Tenasserim it is less common than in other parts of the province.

Indaing forest, so typical of laterite formations, has already been described under *Dipterocarpus tuberculatus*, the *in* tree, which forms the principal constituent of the normal form of *indaing*: *Pentacme suavis* (*ingyin*) and *Shorea obtusa* (*thitya*) together are the two most important companions of the *in*, all three species occurring gregariously together. The relative proportion of *in* on the one hand, and *ingyin* and *thitya* on the other, varies considerably; the two latter usually occur together, though there are exceptions to this, while the *in* is occasionally found without the other two. *Ingyin* and *thitya*, on the other hand, are often found without *in*, particularly on ridges and other dry localities, for they appear to be able to survive in less favourable situations than the latter species. Apart from laterite, they are most commonly found on dry sandstone formations and sometimes on red clay. They may be said to occur in varying types of forest from *indaing* of the normal type through various forms of semi-*indaing* to dry deciduous mixed forest with varying associates, and may be found even in fairly moist types of forest. Fig. 16 shows a good quality of *indaing* forest in which *Pentacme suavis* is the most plentiful species.

Some examples of the occurrence of this tree may be quoted. On some of the dry ridges of the Chindwin drainage *ingyin* and *thitya* occur on sandy, often shallow soil, associated with oaks (*Quercus spicata* and *Q. Brandisiana*), *Buchanania latifolia*, *Strychnos Nux-blanda*, *Garuga pinnata*, *Gardenia erythroclada*, and *Cycas siamensis*. In parts of the dry zone of Upper Burma they occur on sandstone formations, in which silicified wood (Burmese *ingyin-kyauk*) is sometimes found, the soil often being poor and shallow. Here *ingyin* and *thitya* of rather small dimensions are found associated with other trees of stunted growth, of which the chief are *Terminalia tomentosa*, *Diospyros burmanica*, *Phyllanthus Emblica*, *Acacia leucophloea*, *A. Catechu*, *Buchanania latifolia*, *Tectona Hamiltoniana*, *Xylia dolabriformis*, *Odina Wodier*, *Schleichera trijuga*, *Dalbergia paniculata*, and *Cassia renigera*. In the driest places *ingyin* and *thitya* give place to *Tectona Hamiltoniana*, *Terminalia Oliveri*, *Acacia leucophloea*, *A. Catechu*, and other species typical of the dry zone.

In the Pegu Yoma, where the formation is sandstone and shale, *ingyin* and *thitya* become more plentiful towards the north of the range, where the climate and the type of forest are drier than in the south. Thus in the Sinthè reserve of the Pyinmana division, which borders on the dry zone, the rainfall being about 40 in., *ingyin* and *thitya* are the commonest species, forming 13·2 per cent. of the total growing stock as against 7·6 per cent. for teak and 1·2 per cent. for *in*. In the Pozaungdaung reserve of the same division they form 10·4 per cent. of the growing stock as against 7·1 per cent. for sound teak, while in the East Yoma, Satsuwa, and Tindaw reserves of the Thayetmyo divisions they form 7 per cent. of the stock as against 15 per cent. for teak. The reserves in question are primarily teak reserves, the *thitya* and *ingyin* occupying mainly the drier sandstone ridges, and these figures therefore indicate that a very considerable quantity of *ingyin* and *thitya* occurs along these ridges in the drier types of mixed deciduous forest in the Pegu Yoma. Associated with them in such localities are *Pterocarpus macrocarpus*, *Terminalia tomentosa*, *Odina Wodier*, with rather stunted teak and *Xylia dolabriformis*, and often *Dipterocarpus tuberculatus*. Where bamboos are present the commonest species are *Dendrocalamus strictus* in the driest situations, and *Oxytenanthera albociliata*, *Cephalostachyum pergracile*, and *Bambusa polymorpha* elsewhere.

Ingyin and *thitya* are not necessarily confined to poor dry localities. They sometimes occur in fairly moist fertile tracts, even associated at times with *kanyin* (*Dipterocarpus turbinatus* and *alatus*), and here the trees attain very large dimensions. There is often a comparatively heavy undergrowth in such localities. In the better types of *indaing* forest, also, where *ingyin* and *thitya* are mixed with *in*, they often attain large size, trees 10 or 12 ft. in girth being not uncommon.

As regards climatic conditions, *ingyin* and *thitya* in their natural habitat occupy regions where the absolute maximum shade temperature varies from 100° to 110° F., the absolute minimum from 35° to 50° F., and the normal rainfall from 30 to 100 in. or more. Where the rainfall is below 40 in. the trees are somewhat stunted.

LEAF-SHEDDING, FLOWERING, AND FRUITING. *Pentacme suavis* is the most deciduous of all the dipterocarps. In fertile localities it is leafless for a comparatively short time or may be scarcely quite leafless, but in dry situations it may drop its leaves towards the end of January or early in February and remain leafless till April. The large inflorescences of showy yellow fragrant flowers appear in March, when the tree is leafless or nearly so, and the fruits ripen in May and June. The fruit is five-winged, three of the wings being larger than the other two; the larger wings are about 3–3½ in. long. Like that of other dipterocarps, the seed germinates soon after falling, and will not keep any time; it is also subject to the attacks of insects.

SILVICULTURAL CHARACTERS. *Pentacme suavis* belongs to the xerophilous type of dipterocarps (see p. 32), and, with *Shorea obtusa*, represents the limit of that type in the Indo-Burman region, extending into drier situations, and occurring on poorer soil and more rocky ground than any of the other dipterocarps. Its adaptations for persisting in such localities are seen in its comparatively thick rough bark, its long taproot, its deciduous character, and the red colour not only of the young leaves, but also of the older ones. Further, Ryan and Kerr[1] note the occurrence of two well-marked varieties, one in which the young shoots and stipules are glabrous and the other in which they are tomentose, the latter being characteristic of dry situations and the former of more fertile localities. The period of growth is short, commencing at the end of March and usually continuing for a month to six weeks, after which it ceases. The tree coppices well up to a moderate size, and Ryan and Kerr note that they have found it producing root-suckers very occasionally; this would indicate a further special adaptation, not possessed by dipterocarps in general, for surviving in dry localities.

NATURAL REPRODUCTION. As a rule the tree regenerates freely, but in years of deficient rainfall the seedlings are known to die from drought in the monsoon months in dry situations. It has not yet been determined if dying back for some years, with subsequent establishment of the seedling, takes place with this species. As in the case of the sal, successful germination depends on the timely commencement of the rains when the fruits fall, since the seed loses its vitality quickly and fails to germinate if it lies any time on dry ground, particularly if exposed to the sun.

4. SHOREA, Roxb.

Seven species in the Indo-Burman region. Fruit with three long wings.

Species 1. *S. robusta*, Gaertn. f.; 2. *S. Tumbuggaia*, Roxb.; 3. *S. obtusa*, Wall.; 4. *S. Talura*, Roxb.; 5. *S. assamica*, Dyer.

1. **Shorea robusta,** Gaertn. f. Sal. Vern. *Sál*, *sála*, *sálwa*, *sákhu*, Hind.; *Sakwa*, Nep.; *Shál*, Beng.; *Sálwa*, *soringhi*, Uriya.; *Sarai*, *rinjal*, C.P.; *Gúgal*, Tel.

A large gregarious tree, seldom quite leafless, with shining foliage, the mature leaves somewhat coriaceous, ovate-oblong, usually about 4–8 in. long.

---

[1] Journ. Siam Soc., viii (1).

Crown conical or elongated in youth, afterwards rounded with a strong branch-system. Bole clean and straight in forest-grown trees. Bark of saplings greyish brown, smooth, with a few deep longitudinal cracks; that of older trees dark brown, 1–2 in. thick, rough, with deep longitudinal furrows. Sapwood small, pale coloured, heartwood brown, hard, cross-grained, very strong and durable, seasoning slowly. This is one of the most important timber trees of India; the wood is extensively used for building construction of all kinds, railway sleepers, wagons, and a large number of other purposes. The tree when tapped yields a whitish resin which is burnt as incense and used for caulking boats. Apart from the technical properties of its timber, the gregariousness of the sal renders it specially important in that the timber is obtainable in abundance within the tracts occupied by it.

In favourable localities the sal reaches a height of 120 ft. and a girth of 12 ft. or more. According to Brandis, in the gorges at the foot of the hills in Nepal it may attain a height of 150 ft. with a clear stem of 60–80 ft. and a girth of 20–25 ft. A tree 25 ft. 8 in. in girth was measured in 1910 in the Chilkia range of the Ramnagar forest division, United Provinces. Gamble mentions a tree in the valley of the Great Rangit, in the Darjeeling hills, which was 161 ft. high, 86 ft. to the first branch, and 10 ft. 8 in. in girth at 4 ft. from the ground. Such dimensions, however, are quite exceptional; under average conditions the tree ordinarily attains a height of 60–100 ft. with a girth of 5–7 ft., while under less favourable conditions it becomes stunted, reaching a maximum height of only about 30–40 ft.

GENERAL DISTRIBUTION. The sal occupies two main regions separated by the Gangetic plain, namely, the northern and the central Indian regions. In the former the extreme north-western limit is in the Kangra district of the Punjab, where there is an outlying area in which the growth of the trees is stunted. The main and almost continuous stretch of sal forest in the northern region commences with the Kalesar forest in the Ambala district, on the right bank of the Jumna, and stretches along the sub-Himalayan tract as far east as the Darrang district of Assam. In places the sal extends some distance out into the plains; it also runs into the outer Himalayan valleys, and ascends the outer hills to 4,000 ft. and occasionally to 5,000 ft. South of the Brahmaputra river in Assam it is found in the Garo hills, Nowgong, Kamrup, and the Khasi and Jaintia hills: there is still a considerable area of sal in the Jirang state and a smaller area in the Nongkhlaw state, but the sal tracts are scattered and much cut up by shifting cultivation.

In the central Indian region the sal commences near the Ganges in the Santal Parganas and extends southwards through Chota Nagpur and the Orissa Feudatory States to the Madras Presidency, where it occurs chiefly in the Ganjam district and to a small extent in Jeypore and in the Palkonda range of Vizagapatam. To the west there are considerable areas of sal forest in the Central Provinces chiefly in the Bilaspur, Mandla, Balaghat, Jubbulpur, and Raipur districts.

Although the general distribution of the sal is governed mainly by climate, its local distribution is governed largely by conditions of geology and soil.

CLIMATE. The regions in which the sal is found vary widely as regards both temperature and rainfall. In the western Himalaya it ascends in places to regions where it encounters occasional snowfall, and where the maximum shade temperature is not much above 90° F. In the valleys of the western sub-Himalayan tract, as well as in parts of the central Indian region, it is exposed to severe frost, and suffers considerably from its effects. In parts of Chota Nagpur and the Central Provinces it grows in localities where the temperature may rise to 115° F. or more, and where frost is unknown. In the eastern part of its northern region it thrives in a moist but equable climate, where the normal rainfall may be as much as 180 in. and the maximum temperature is not much above 100° F. Nowhere does it enter regions where the climate approaches aridity. Taking its habitat as a whole, the absolute maximum shade temperature varies from about 93° F. at high elevations to about 117° F. in the hottest part of Chota Nagpur, and the absolute minimum varies from under 30° F. to about 45° F., while the normal rainfall varies from 40 to 180 in.

In its northern region its range on the west is limited by the fact that it begins to enter localities which are too dry and in which the extremes of temperature are too great: in the Kangra valley the rainfall varies from 50 to 100 in., which is considerably higher than in the submontane tracts outside, and this probably accounts for the existence of a small area of sal as an outlier in that locality. On the east, in Assam, the range of the sal is limited mainly by the humidity of the climate, which induces a luxuriant growth of evergreen species and a dense undergrowth, resulting in soil conditions unfavourable to the establishment of seedlings, and producing a struggle for existence against shade-bearing competitors which the sal is unable to survive. Similar unfavourable conditions have been produced artificially farther west in the Duars by prolonged fire-protection, as will be explained later.

In the central Indian region the limits of the sal are defined partly by climatic conditions, in that it does not extend into the driest tracts, and partly by the local geological formation.

TOPOGRAPHY, GEOLOGY, AND SOIL. Sal forests occur both in hilly country and on flat ground. In the former the sal is found, as a rule, in stunted form on the ridges; in dry hot localities it avoids the ridges altogether, seeking the moister and cooler aspects and depressions. It grows best on the lower slopes and in the valleys where the soil is deep, moist, and fertile. Some details of its occurrence in different situations are given below.

As regards geology and soil, the sal is found on a variety of geological formations, and is capable of growing on various types of soil provided the soil water-content is neither too low nor too high to enable it to establish itself. Within its habitat it avoids soils which, although otherwise thoroughly suitable for its growth, become too dry for its survival in the season of scanty rainfall. Mr. Hole[1] has shown that sal seed germinates very successfully even in pure sand provided it is sufficiently moist, but that the seedlings die of drought if the soil water-content falls to 3 per cent. in sand or sandy loam and to 10 per cent. in loam. This accounts for the well-known fact that sal is never found in the sandy and shingly river-beds which are so common in the sub-Himalayan region. Here, although the seed may germinate in the rains, the seedling cannot survive the dry season: these river-beds are occupied by forests of *Acacia Catechu* and *Dalbergia Sissoo*, or at a later stage by dry miscellaneous forest. Swampy tracts in the neighbourhood of the sal forests are also avoided by the sal, which cannot survive the permanent excess of soil moisture; such ground is occupied by typical swamp trees, such as *Eugenia Jambolana*, *Trewia nudiflora*, *Diospyros Embryopteris*, *Bischoffia javanica*, and others. It is not the water as such that the sal avoids, but the bad drainage causing a want of sufficient aeration in the soil: actually the tree will grow with its roots in running water.

---

[1] *Ind. For. Records*, vol. v, pt. iv, p. 17.

The most favourable soil for the growth of the sal is a well-drained moist deep sandy loam with good subsoil drainage, and hence the tree thrives well on deep boulder deposits overlain by a sufficient depth of fertile porous loam. On some of the deep boulder deposits and elevated river terraces flanking the outer Himalaya the sal thrives extremely well and reaches large dimensions. An excess of clay in the subsoil, on the other hand, produces stunted and unhealthy growth, as will be seen in the description of forest types given below. In the alluvial tracts of the plains the sal is usually of better quality on the high ground which frequently skirts the banks of streams, and may extend for a distance of some hundreds of yards from them, than on the lower ground farther from the streams. The explanation is probably to be found in the greater porosity of the soil and the better drainage in the case of the high ground near streams than on the lower ground where water collects annually in the rains, bringing with it fine clayey particles which settle year after year in the soil and render it impervious to air and water.

The distribution and character of the sal forests of the sub-Himalayan tract, as will be seen presently, are influenced in no small degree by the *bhabar* and *tarai* formations. The former is a stretch of deep dry boulder deposit skirting the base of the outer hills. It commences some distance to the east of the Ganges and stretches eastward to Assam, with occasional breaks. In the United Provinces its maximum width is about 13 miles, and it slopes down from about 1,200 ft. at the base of the hills to about 800 ft. at its outer limit. This *bhabar* deposit is extremely porous, and all but the larger rivers and streams sink into the ground on issuing from the hills, their beds remaining dry except in the flood season. The surface of the *bhabar* tract is waterless, though cultivation is carried on by irrigation with the aid of masonry canals and channels. The natural water flows at a great depth below the surface until it reaches the outer limit of the *bhabar* tract. Here it is brought to the surface by underlying clay deposits, and a series of springs marks the commencement of the *tarai*, a tract of swamps, quicksands, and streams full of water, sometimes of considerable depth. In the United Provinces the maximum breadth of the *tarai* is about 8 miles, and it slopes gently down from about 800 ft. to 650 ft. at its outer limit, where the land of swamps is left behind and the plains of northern India commence. The types of sal forest on the *bhabar*, *tarai*, and plains will be considered in the next section.

As regards underlying rock, in the sub-Himalayan tract the sal occurs on the older Himalayan rocks of the outer ranges, consisting chiefly of shale or mica schist with occasional limestone; on the tertiary sandstones, shales, and conglomerates of the Siwalik range flanking the Himalaya proper; and on the deep boulder deposits skirting the base of the hills and lining the outer valleys in many places. Where pure limestone appears within its region, the sal seems to avoid this rock; it thrives well, however, where the soil consists partly of limestone debris, and it may be concluded that the objection is not to the lime itself but to the physical properties of the limestone rock, which is too dry for the sal. In the Dun sal avoids the dry shallow soil overlying calcareous tufa, which forms a hard pan. In the sub-Himalayan tract of Assam the sal occurs on the schists of the outer Himalaya and on granitic rock, as on Singri hill in Darrang, as well as on the sandstones and conglomerates of the lower hills and the deep boulder beds flanking the outer ranges. In the Guma reserve of Goalpara it occurs on a red lateritic formation overlying boulder beds.

In its central Indian or peninsular region the sal occurs on a variety of geological formations, of which the chief are gneiss, mica schist, quartzite, shale, sandstone, and laterite; it is found occasionally on limestone, and also occurs on alluvial ground overlying older rocks. The sal does not necessarily occur on all these rocks in different localities. In the drier regions it may be absent from a geological formation which it frequents in a moister climate, while the local form of a particular rock may effect the occurrence of sal on it. The central Indian region comprises for the most part forests of a somewhat dry type, and hence the occurrence of sal is determined largely by the hygroscopicity of the rock and soil. A noteworthy instance of this is its almost complete absence on the Deccan trap, where its place is taken by the teak. In the few cases in which sal enters the trap region it occurs, as a rule, sparsely and in stunted form, but there are exceptional cases in which sal forest of very fair quality occurs on trap. This avoidance of trap is evidently due to the fact that this rock and the soil produced by it are not sufficiently retentive of moisture, since on the edge of the trap a comparatively small admixture of decomposing laterite may produce a soil on which sal can thrive. Where sal does grow on trap this is no doubt due to the fact that the subsoil water-content is higher than is usually the case on this geological formation. Sal thrives well on laterite provided it is in a sufficiently decomposing state to produce some depth of soil: on hard laterite with a shallow soil it is stunted or may be entirely absent. The tree is not averse to highly ferruginous soils. Sal forest of very fair quality occurs in Singhbhum on hills consisting of haematite which is in process of being mined; the sal roots penetrate through even the most highly ferruginous portions of the ore.

Among other examples of the effect of geological formation on the distribution of the sal, it may be mentioned that in the Bilaspur district of the Central Provinces sal occurs mainly on gneiss and clay schist, stopping short on the appearance of sandstone, which is here almost in the form of quartzite, and avoiding limestone; the two latter formations appear to be too dry for the establishment of the sal. In the Jubbulpur district various geological formations meet; sal is, practically speaking, confined to the Upper Gondwana formation, consisting of earthy sandstones and clays, while teak adheres to the trap and Vindhyan areas, the latter comprising more porous sandstones with shale and limestone.

Types of forest and local occurrence. The sal is one of the most gregarious of Indian trees; it tends to regenerate in masses where conditions are favourable, and to grow up in more or less even-aged crops of varying extent in which it is pure or forms the bulk of the stock in mixture with other species. Even-aged more or less pure crops of appreciable extent are particularly characteristic of flat or gently sloping ground which was formerly devoid of tree growth, for example, grassy savannahs or abandoned cultivation ; here, if conditions are favourable, the sal springs up in gregarious masses, often forming crops of great density (see Fig. 17). Where grassy blanks occur within the sal forests the sal tends to spread gradually into them and to re-stock them. Fig. 18 shows sal pole forest bordering a grassy blank, and gives an idea of the gregarious character of the tree. On grassy savannahs the sal also tends to spread outwards from isolated seed-bearers or groups of seed-bearers ; small pure even-aged groves of sal are thus formed (Fig. 19). These in course of time spread outwards by degrees, sometimes forming a series of even-aged crops in different stages of development.

Although the natural tendency of the sal is to spring up gregariously and to form even-aged crops, it also occurs frequently in uneven-aged crops, and may also be found more or less scattered by single trees or in small patches among various other species. This is frequently seen in hilly or broken country, where conditions for reproduction and growth constantly vary from place to place within narrow limits of area. It is also seen in cases where sal is gradually encroaching into miscellaneous forest, or where it is being gradually ousted by other species. Cases of the former are frequent in the *bhabar* tract of the United Provinces, while cases of the latter may be noticed in the moist forests of the Bengal Duars, where the sal is being ousted by evergreen species.

The sal is associated with various other species, some of which are characteristic of distinct types of sal forest. As these companion species differ to some extent in different localities they will be considered in dealing with local types. In some localities sal in mixture with bamboos (*Dendrocalamus strictus*) is not uncommon, particularly on hilly or undulating ground.

Sal forests in general can be separated into two extreme types, the dry and the moist types : between the two various gradations occur. The dry type is characteristic of dry and often hilly country, denuded or hard ground, and shallow soil ; in this type the commonest companion of the sal is ***Buchanania** latifolia*, and in some localities *Diospyros tomentosa* or *D. Melanoxylon*. Dry types are well represented in the central Indian region and in the western part of the northern region. The extreme of the moist type is seen in the moist sal forests of Bengal and Assam, where the sal is associated with various evergreen species. Intermediate types, tending towards the moist rather than the dry type, may be found in many parts of the United Provinces and in the fertile valleys of Chota Nagpur.

Sal forests are inseparably connected with grass-lands, which may consist of small grass-covered blanks within the forests or of extensive savannah tracts within or adjacent to them, and into which the sal tends to spread where conditions are favourable. The savannah grasses are excellent indicators of the suitability or otherwise of a given locality for the growth of sal. An account of the more important grasses of the Dehra Dun neighbourhood has

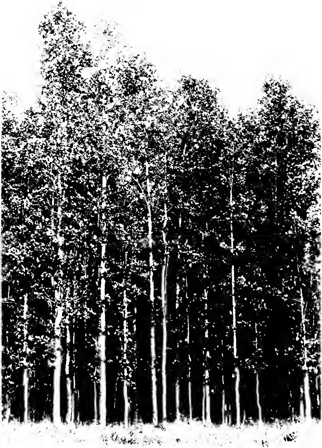

FIG. 17. *Shorea robusta*, dense even-aged pole crop, Dehra Dun, United Provinces.

Fig. 18. *Shorea robusta* pole forest along edge of grassy blank, in which natural reproduction is gradually appearing. Dehra Dun.

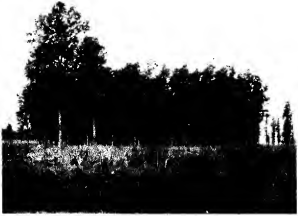

Fig. 19. *Shorea robusta*, dense pole crop sprung from isolated seed-bearers on a grassy plain. Patli Dun, United Provinces.

been written by Mr. Hole.[1] The most characteristic savannah grass of the sal tracts is *Saccharum Narenga*, Wall., the *kanwal* of northern India or *bata* of Assam, a tall grass, the culms of which attain 16 ft. in height. Its presence denotes soil conditions eminently suitable for sal, and it is the dominant grass of the sal tracts, not only in open savannahs, but also beneath the partial shade of the forest where the canopy is sufficiently open. Frequently associated with it, and also denoting soil conditions suitable for sal, is *Anthistiria gigantea*, Cav., the giant spear-grass, a variety of which, however, occurs in low-lying ground unsuitable for sal. *Saccharum spontaneum*, Linn., the *kans* grass, sometimes occurs with *S. Narenga* in localities suitable for sal, but it is also frequent on low-lying moist ground where sal will not grow, while a variety of the same grass is found on sandy soil in dry river-beds incapable of supporting sal.

Saccharum Munja, Roxb., the *munj*, is the dominant grass on the sand and shingle of dry river-beds in the neighbourhood of sal forests; it is associated with *Acacia Catechu* and *Dalbergia Sissoo*, but denotes soil conditions too dry for sal to thrive. With it, and denoting similar or even less favourable conditions, are *Andropogon monticola*, Schult., *Aristida cyanantha*, Steud., and *Triraphis madagascariensis*, Stapf. The last named, however, sometimes occurs in very dry types of sal forest, as in Goalpara. *Erianthus Ravennae*, Beauv., is a tall grass not unlike *Saccharum Munja* in general appearance, with culms reaching 20 ft. in height. Although sometimes associated with *S. Narenga* in sal tracts, it denotes a higher degree of soil moisture than the latter grass, and is more typical of the moist mixed forests.

Imperata arundinacea, Cyrill., the *siru*, well known in Burma as *thekkè*, occurs in sal tracts, and denotes widely varying soil conditions. It occurs with *Saccharum Narenga* in localities suitable for sal: here it often becomes dominant as a result of the weakening of *S. Narenga* by constant cutting or grazing, which prevents the latter forming seed, whereas *Imperata* seeds freely under such conditions, while its creeping stolons make it more resistant to fire and other injuries and more difficult to eradicate by cultivation. Thus *S. imperata* often becomes dominant on fire-lines or roads running through tracts of *S. Narenga*. *S. imperata* very commonly indicates stiff clayey water-logged ground unsuitable for sal. It is, however, also found on dry sandy soils in dry sal or mixed forest, as on the southern slopes of the Siwaliks, or on poor denuded ground in dry open sal forest, as in the Jaspur forest near Ramnagar.

The more characteristic tall grasses of the low-lying wet and swampy tracts which are too moist for the growth of sal are *Phragmites Karka*, Trin., the *nal* or *narkal*; *Arundo Donax*, Linn., the giant reed; *Saccharum fuscum*, Roxb., the *retwa*; and *Saccharum procerum*, Roxb., the *ekra* of the low-lying savannahs of Bengal and Assam.

The local occurrence of the sal in the principal sal-bearing tracts may now be considered.

Punjab. In the small outlying sal areas of the Kangra district and the Siwalik hills of the Hoshiapur district the sal is at its northern limit, and occurs in stunted form. Its extreme limit in the Kangra district is on the west bank of the Beas on an isolated hill, where with *Quercus incana* it forms an underwood to *Pinus longifolia*. Farther east in the Siwaliks it occasionally forms pure patches on flat-topped hills, but as a rule occurs as an underwood to *Pinus longifolia*. The rainfall is about 50–60 in. The only other sal tract in the Punjab is the Kalesar forest in the Ambala district on the west bank of the Jumna river. As it is near its northern limit, and suffers from frost, the sal does not attain large dimensions. This forest marks the western limit of the great sub-Himalayan sal tract which stretches eastward to Assam.

---

[1] R. S. Hole: On some Indian Forest Grasses and their Oecology. Ind. For. Mem. vol. I, Bot. Ser. I, 1911.

United Provinces. Sal forests occur in a more or less continuous belt along the sub-Himalayan tract and outer hills from the Jumna to the Gandak river, and extend some distance into Nepal. The chief companions of the sal are *Terminalia tomentosa* (often on clay), *T. belerica*, *T. Chebula* (local), *Lagerstroemia parviflora*, *Eugenia Jambolana* (in moist types), *E. operculata* (especially in grassy tracts), *Adina cordifolia*, *Stephegyne parvifolia*, *Stereospermum suaveolens*, *Ougeinia dalbergioides*, *Miliusa velutina*, *Saccopetalum tomentosum* (Oudh), *Holarrhena antidysenterica*, *Wrightia tomentosa*, *Mallotus philippinensis*, *Garuga pinnata*, *Kydia calycina*, *Buchanania latifolia* (common in the drier and hill types), *Schleichera trijuga*, *Odina Wodier*, *Cassia Fistula*, *Anogeissus latifolia*, *Butea frondosa*, *Bauhinia malabarica*, *Casearia glomerata*, *C. tomentosa*, *Bridelia retusa*, *Dillenia pentagyna* and *D. aurea* (plains forests of Oudh), *Careya arborea*, *Phyllanthus Emblica*, *Diospyros tomentosa* (in dry types), *Semecarpus Anacardium*, *Randia dumetorum*, *Gardenia turgida* (on grass-lands), *Croton oblongifolius* (Oudh), *Cordia Myxa*, *Ehretia laevis*, *Grewia* spp. and species of *Ficus*, of which the commonest is *F. bengalensis*.

The most important climbers in the sal forests are *Bauhinia Vahlii*, *Spatholobus Roxburghii*, and *Millettia auriculata*.

The sal forests of the United Provinces may be classified broadly, according to topography, into (1) forests of the hills and narrow valleys, (2) forests of the river terraces, (3) forests of the *duns*, (4) forests of the submontane and *bhabar* tracts, (5) forests of the *tarai* and plains. This classification is a somewhat arbitrary one, and it is not always easy to draw a sharp line between the broad classes; a classification of this kind, however, is convenient for descriptive purposes.

1. The hill forests vary greatly in type and quality. In the outer Himalaya the sal ascends to 4,000 ft., and exceptionally to 5,000 ft. Towards its upper limit it is associated, in somewhat stunted form, with *Pinus longifolia*. In a few places the pine descends into the valleys, where it may be found mixed with the sal: here the latter suffers from frost, and in fire-protected areas the pine is tending to spread and supplant it. On the upper and drier hill-slopes the sal occurs mainly in patches in moist depressions and on cool aspects, the hotter and more exposed slopes being clothed, as a rule, with dry mixed forest. On the upper slopes the sal is usually stunted; its commonest companion here is *Buchanania latifolia*. East of the Ganges the sal is often associated with bamboos (*Dendrocalamus strictus*). On the lower slopes and in the ravines, where the soil is moist and fertile, it often reaches very large dimensions, and produces a tall straight bole; its chief companions here are *Terminalia tomentosa*, *Adina cordifolia* of large size, and moisture-loving species such as *Eugenia Jambolana*, *Bischoffia javanica*, *Cedrela Toona*, and others. In some types of

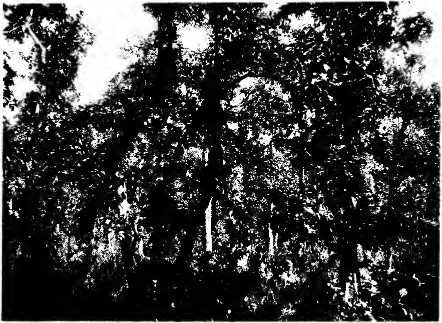

FIG. 20.—*Shorea robusta* forest of poor quality on stiff clays, Gorakhpur, United Provinces.

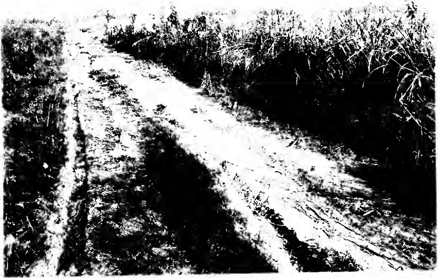

Fig. 21.—*Shorea robusta*: fire-protected *chaudar* (on right of road) in April with thick growth of *ulla* grass (*Anthistiria gigantea*), Pilibhit, United Provinces.

outer hill forest the sal tends to grow less pure than in the plains, even where the locality suits it well. Many exceptions occur however, one of the most marked being seen in the case of gentle slopes on boulder formation, where dense nearly pure even-aged crops occur, sometimes of good quality, sometimes rather stunted. These crops appear to have arisen on former open blanks which were probably cultivated at one time. Areas formerly under cultivation in the outer hills are sometimes marked by the presence of sal pole crops with a plentiful admixture of *Ougeinia dalbergioides*. The latter is one of the first species to make its appearance on abandoned cultivation in these tracts, and the sal comes in when a favourable year for reproduction takes place, and makes its way through the *Ougeinia*.

Sal of small size is found throughout the dry Siwalik hills of the Saharanpur district, on tertiary sandstone, shale, and conglomerate. Here its chief associates are *Buchanania latifolia*, *Anogeissus latifolia*, *Stereospermum suaveolens*, *Ougeinia dalbergioides*, and in dry places *Cochlospermum Gossypium*; the palm *Phoenix humilis* frequently accompanies it, and on the higher ridges it is mixed with *Pinus longifolia*. It is seen at its best in sheltered ravines, where it forms gregarious patches of well-shaped poles which, however, do not reach a large size; in such places its chief companion is *Buchanania latifolia*.

2. Sal forests of the river terraces. These forests are situated at the base of the outer hills and along the chief river valleys on elevated flat or slightly sloping boulder terraces. The soil is deep, porous, and well drained, and the water-level is usually at a considerable depth, the terraces often being at a height of 150 to 200 ft. or more above the level of the stream. On these terraces sal occurs in well-stocked, even-aged, and remarkably pure crops. These terraces contain some of the best sal forest in the province, the growth and quality being as a rule excellent, and the trees reaching a great height in favourable localities.

3. Forests of the *duns*. The *duns* are broad valleys within the outer ranges of hills. The two best known are the Dehra Dun, lying between the Siwalik hills and the Himalaya proper, and stretching from the Jumna to the Ganges, and the Patli Dun, drained by the Ramganga river: there are also smaller and less well-known *duns*. These *duns* contain different well-marked types of forest, namely (*a*) riverain forests on recent alluvial beds of sand and gravel, the predominating species being *Dalbergia Sissoo* and *Acacia Catechu*; (*b*) dry mixed forests, containing *Acacia Catechu*, *Garuga pinnata*, *Bombax malabaricum*, *Odina Wodier*, *Holarrhena antidysenterica*, and other species; the dominant grass is *Saccharum Munja*, while on dry shingle-beds and other dry places occur also *Aristida cyanantha*, *Triraphis madagascariensis*, *Andropogon monticola*, and the dry form of *Saccharum spontaneum*; (*c*) moist mixed forest, with swamp forest as an extreme form; the dominant grass is *Erianthus Ravennae*, while the tree species vary with the degree of moisture, and include *Dalbergia Sissoo*, *Eugenia Jambolana*, *Bombax malabaricum*, *Garuga pinnata*, *Holarrhena antidysenterica*, and many others, and in the moistest parts *Cedrela Toona*, *Trewia nudiflora*, *Diospyros Embryopteris*, *Pterospermum acerifolium*, *Ficus glomerata*, *Bischoffia javanica*, *Albizzia procera*, and other swamp species; (*d*) sal forests, occupying the elevated ground well above the level of the rivers. The origin of the sal forests is to some extent

a matter for speculation, but in some cases there is undoubted evidence that they represent a stage in progressive succession subsequent to the dry mixed forest stage, the sal having gradually established itself in these forests as the soil became moister and more fertile with successive stages of tree-growth. The sal forests of the *duns* are characterized by the presence of grass-lands in which the dominating grass is usually *Saccharum Narenga*: many of these appear to be of artificial origin, and were probably at one time cultivated. These valleys are subject to severe frost, particularly in the low-lying parts, and reproduction is killed back, while severe damage is often done to saplings and poles. As the hills surrounding the valleys are ascended, the risk of frost damage becomes less. In spite of the frost the sal tends to spread into the grass-lands where soil conditions are favourable. Fig. **18** shows the edge of a sal forest in the Dehra Dun valley, with sal reproduction gradually establishing itself in an adjacent grassy blank subject to severe frost. The sal forests of the Dehra Dun valley are situated on deep boulder deposits with water at a great depth; where these deposits are overlain by fertile loam the sal reaches fair dimensions considering that the locality is near the northern limit of the species.

4. Forests of the submontane and *bhabar* tracts. The sal forests of the submontane tracts occupy broken ground or boulder deposits along the base of the outer hills; they vary much in type and quality. On deep boulder deposits and old terraces they resemble the forests of the river terraces, the crops being often even-aged and remarkably pure. On fertile ground, crops of excellent quality are produced along the base of the hills, for example in the Lakmanmandi and Sunmanthapla blocks to the east of Haldwani and in the Lachampur block to the east of Ramnagar. In the drier submontane tracts the forest is of a poorer type, and in places is mixed largely with *Buchanania latifolia*: this type of forest is exemplified on the gently sloping ground on the south of the Saharanpur Siwaliks. In some portions of the sub-Himalayan tract, for example outside the foot-hills in the Gonda district, the sal occurs on broken ground intersected by ravines; this ground is occupied in places by poor dry mixed forest, the sal occurring in pockets in the moister depressions. On the outskirts of this broken country, where the ground dips down to more level country and becomes moister, sal forest of excellent quality is found in a somewhat narrow strip, for example at Chandanpur. The *bhabar*, as explained above, is the deep waterless boulder tract which stretches in places along the base of the hills. The typical forests of the *bhabar* are not sal forests but dry mixed deciduous forests of a rather open character, in which the commoner trees are *Holoptelea integrifolia*, *Hymenodictyon excelsum*, *Bombax malabaricum*, *Odina Wodier*, *Garuga pinnata*, *Lagerstroemia parviflora*, and *Acacia Catechu*, while *Pterocarpus Marsupium* is common in the eastern Kumaun *bhabar*. In the river-beds occur forests of *Dalbergia Sissoo* and *Acacia Catechu*, while in moist situations *Trewia nudiflora*, *Eugenia Jambolana*, and other moisture-loving species are found. In the *bhabar* tract the sal forests occur in situations where the soil is in a condition intermediate between the dry ground supporting the mixed deciduous forest and the low-lying wet ground where the moist forest occurs. The sal is found on well-drained situations with a good loamy soil,

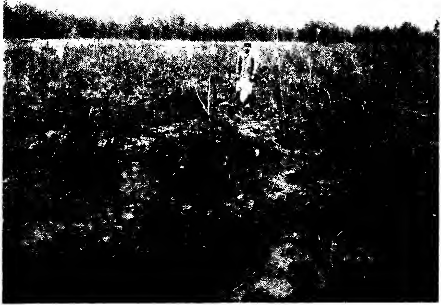

FIG. 22.—*Shorea robusta*: burnt *chaukar* in April, showing dead sal shoots of previous year, and new leafy shoots of current year appearing. Pilibhit, United Provinces.

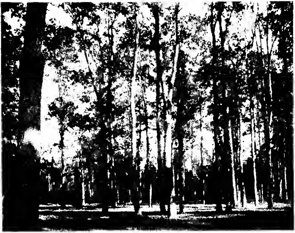

Fig. 23. *Shorea robusta* mature forest of good quality, high-level type, North Kheri forests, United Provinces. Undergrowth cleared for camping.

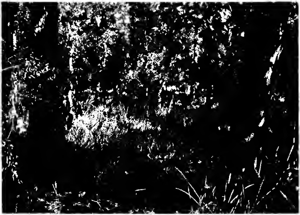

Fig. 24. *Shorea robusta* open forest, low-level type with soil-covering of grass, chiefly *Saccharum Narenga*, and no reproduction. Kheri Trans-Sarda forests, United Provinces.

elevated well above the level of the rivers and streams. Sal seedlings may sometimes be found in quantity in the mixed deciduous forests where soil conditions are favourable, and some of these forests are in process of being transformed into sal forests.

5. **Forests of the *tarai* and plains.** The *tarai* has been described above as the tract of springs, swamps, and streams fringing the outer edge of the waterless *bhabar* and separating it from the plains proper. The *tarai* country merges insensibly into the plains, and it is difficult to discriminate between *tarai* and plains sal forest, more especially as the water-level throughout the forests of these tracts is comparatively near the surface, and swamps and streams are plentiful. In what may be called the true *tarai* type of forest, which occurs in a belt at the outer edge of the *bhabar*, where springs, swamps, and deep streams are abundant, the sal does not occur on the low swampy ground, but on flat elevated plateaux about 15 to 20 ft. above it; these plateaux mark the original level of the country. The sal is of poor quality and rather stunted. Among its chief companions are *Mallotus philippinensis*, *Lagerstroemia parviflora*, *Stercospermum suaveolens*, *Terminalia tomentosa*, *Schleichera trijuga*, *Eugenia operculata*, and *Butea frondosa*. Climbers are sometimes plentiful, particularly *Bauhinia Vahlii*, *Spatholobus Roxburghii*, and *Millettia auriculata*. In some parts of the *tarai*, especially where grazing has been heavy, the ground becomes hardened and much eroded, so that the plateaux become intersected by water-channels cut in the rainy season and dry throughout the rest of the year, with the result that broken or undulating country is produced. Here the sal forest is usually open and of very poor quality, as in some of the lower parts of the Jaspur forest near Ramnagar: a growth of *Imperata arundinacea* often covers the ground on the higher and more denuded parts, while *Saccharum Narenga* is confined to the more fertile depressions. Farther south towards the plains the sal forests, which are for all practical purposes confined to northern Oudh, are situated on flat alluvial ground with the subsoil water-level at a moderate depth. These forests are of great importance owing to their accessibility and their proximity to cultivated and populated tracts. The sal forests are not found on the lowest ground near rivers; this ground is occupied by the so-called low alluvial forests, consisting of *Acacia Catechu*, *Dalbergia Sissoo*, *Bombax malabaricum*, and other species, while in moist or swampy localities are found such moisture-loving species as *Eugenia Jambolana*, *Trewia nudiflora*, *Barringtonia acutangula*, *Salix tetrasperma*, and others. The sal forests are situated on older and higher alluvium, which is separated from the low alluvium by a well-marked bank, often 20 to 30 ft. high, locally known as a *damar*, representing the old bank of a neighbouring river, which may now be some miles distant. In some places this bank may have become much denuded or intersected by small ravines, and may thus have lost its sharp outline, but the difference in level between the sal forests and the low alluvium nevertheless exists. Apart from this difference in level, there are in some localities distinct differences in level within the sal forests themselves. This is particularly the case in the forests of North Kheri, where two distinct types of sal forest, the high-level and the low-level types, result from a difference in the level of the ground of about 10 ft. The line of separation between the high-level and low-level areas is

marked by a more or less distinct bank, which in places becomes little more than a gentle slope.

The configuration of the ground is further varied by broad shallow clayey depressions: the larger of these usually contain water throughout the year, and take the form of lakes or marshes, while the smaller ones may contain water only in the rainy season. Some of these depressions are mere water-logged grassy blanks within the forest: the sal avoids such places, which tend to fill up with *Terminalia tomentosa*, or in very moist places with *Barringtonia acutangula*. The country is drained by various streams and small rivers running through the forests, the water eventually reaching the Sarda (Gogra), Kauriala, Rapti, or Gandak rivers, and thence draining into the Ganges. In parts of their courses many of the forest streams have silted up in the past, and are now represented by elongated depressions covered with grass, and containing pools of water in places.

In the forests of Oudh the normal rainfall varies from 45 to 55 in., and the absolute maximum shade temperature varies from 110° to 115° F. In some localities, particularly in the Pilibhit and South Kheri forests, damage by frost in the winter is severe; in the North Kheri forests and in Bahraich frost damage is not serious in ordinary years, while in Gonda and Gorakhpur it is usually almost negligible.

The permanent subsoil water-level in the sal forests is never at a great depth. In the North Kheri forests in the cold season it varies ordinarily from 20 to 45 ft., and averages 35 ft. in the high-level forests, while in the low-level sal forests it varies from 13 to 23 ft. and averages 15 ft. The permanent cold weather water-level in the Gorakhpur sal forests is about 12 to 19 ft., in the Tikri forest, Gonda, it is about 15 ft., in the South Kheri forests about 20 to 30 ft., and in the Pilibhit forests about 10 to 15 ft.

The soil is entirely alluvial, but its constituents vary considerably even within comparatively narrow areas. During an investigation into the damage done to the sal forests of Oudh by the abnormal drought of 1907 and 1908 I had occasion in 1910 to have 39 wells dug down to water-level in the forests of Kheri, Pilibhit, Bahraich, Gonda, and Gorakhpur, with the view of examining the soil. In every case the surface soil to a depth of at least 2 ft., but usually more, consisted of sandy loam or clayey loam, while from water-level upwards for a thickness of at least 2 ft., but usually more, there was a deposit of pure sand: this deposit of pure sand frequently extended to more than half-way up from water-level to the surface, and in a few cases reached to within 5 ft. of the surface. Between the pure sand and the surface loam the soil consisted of layers of sandy or clayey loam, or of the two alternating; in exceptional cases there was a deposit of pure clay, sometimes 5 ft. or more in thickness. At or below water-level there was a deposit of clay, sometimes with concretionary calcareous nodules in it. The investigation referred to showed that the physical composition of the subsoil had a marked influence on the amount of damage done by the abnormal drought. The precise action of the drought is explained below (p. 89); it will be sufficient to note here that the damage was most severe in those localities where there was a thick deposit of pure sand in the subsoil. Apart from this, however, the composition of the subsoil evidently exercises a decided influence on the quality of the forest, as indicated

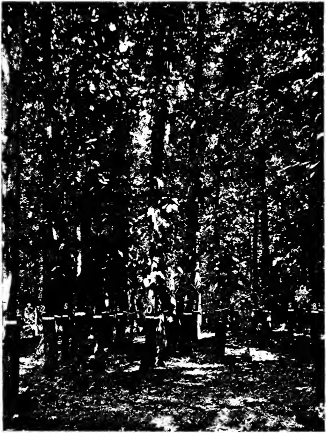

FIG. 25. *Shorea robusta* forest of *phanta* belt type, showing absence of grass where stocking is dense. North Kheri forests, United Provinces.

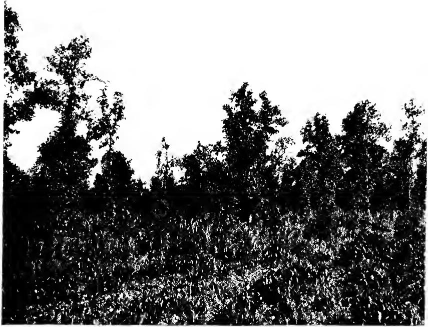

Fig. 26. *Shorea robusta* poor open type of forest. Pilibhit, United Provinces.

by the height-growth. It has been suggested that the quality varies inversely with the depth of the subsoil water-level. It is certainly true that in the North Kheri high-level forests, which are on the whole of better quality than any other sal forests in Oudh, the water-level is at a greater depth than it is elsewhere, and there may be some reason for the assumption. At the same time this would not explain marked differences in the quality of the forest within short distances, the subsoil water-level remaining constant. The presence in the Gorakhpur forests of occasional patches of sal forest of very poor quality was noticed in 1913. In this type, which is shown in Fig. 20, the trees are stunted and often badly shaped, rarely exceeding 45 ft. in height, and the forest is usually rather open, with a soil-covering of grass; one of the most characteristic companions of the sal in this poor type of forest is *Eugenia operculata*. I had a well sunk down to water-level (16½ ft.) in the middle of one of these patches, and this revealed a subsoil totally different from that found in any of the 39 borings made in 1910, namely stiff clay from the surface all the way down to water-level, with only a slight admixture of sand at 8–11 ft., a 3 in. layer of sand at 15 ft., and a little sand at water-level. The poor quality of the forest was undoubtedly due to the stiff clay, causing bad aeration and drainage. Following on this, seven other wells were dug in forest of varying quality, with the general result that the poorer qualities were found in places where there was an excess of stiff clay in the subsoil, and the better qualities were found where the subsoil contained a considerable amount of sand and porous sandy loam.

The effect of a porous well-drained soil on the quality of the plains sal forests is further brought out by a fact noticeable in many localities, but particularly in the Gorakhpur forests, which are somewhat low-lying. Along the banks of streams running through the forests, some of which are now mere depressions, there are almost invariably strips of high ground varying from a few yards to a few hundred yards in width. These have been formed by the accumulated depositions of silt with the overflow of the streams in flood-time; the silt so deposited is coarser and therefore more porous than that which, in the form of fine clayey particles, is spread over the lower ground at a greater distance from the streams. The belt of forest on the high ground, with its porous soil, along either bank of the streams is always of distinctly better quality than the forest on the lower and stiffer ground away from the streams.

Subject to the variations in the configuration of the ground already noted, the sal forests of Oudh present the appearance of extensive stretches of flat forest country in which the sal is almost everywhere the dominant species, and in many places forms over 90 per cent. of the crop. The forests have been under fire-protection for many years. There is a complete system of broad fire-lines dividing the forests into convenient blocks and serving as road alignments; these fire-lines are a characteristic feature in the flat expanses of forest land. The forest tracts themselves are not unbroken stretches of woodland. They contain within their boundaries savannah lands, sometimes of large extent. These grassy tracts are particularly extensive in the North Kheri forests, where they are locally known as *phanta* lands; these are undoubtedly of artificial origin, and were at one time village lands under cultivation. The dominant grass on them is *Saccharum Narenga*. Except in the low-lying parts they are eminently suitable for the growth of sal, and the sal is gradually encroaching on them round the edges of the forest or from clumps of seed-bearers scattered here and there over them. A different class of grass-land is that known locally as a *chandar*, which is common in the Pilibhit and South Kheri forests. These *chandar* lands are subject to severe frosts, and are covered with a natural coppice growth of sal, the shoots of which are killed back year after year by frost, and never appear to make any progress except where specially sheltered or where the frost effects are mitigated by air circulation. The appearance of these *chandar* lands is shown in Figs. 21 and 22, and their origin is discussed below (p. 92). The dominant grasses on them are *Saccharum Narenga* on the higher and *Anthistiria gigantea* on the lower parts. The savannah lands, both *phanta* and *chandar*, are very inflammable, and it has been the custom to burn them annually during the cold season in order to prevent the spread of fire into the sal forests during the ensuing hot season. As a rule a fringe is left unburnt round their edges, with the view of encouraging sal reproduction to spring up and extend into the savannahs.

The types and qualities of sal forest met with on the plains of Oudh vary more than might be expected in a tract of country where the topographical features are at first sight not very pronounced. One of the most remarkable differences in type is seen in the North Kheri forests, where the high-level sal forests are of quite a different character from those on the low-level areas, although the difference in level between the two is only about 10 ft. In the high-level forests the growth is, on the whole, of better quality. Middle-sized trees are plentiful, and dense pole crops are common: everywhere masses of reproduction have filled up pre-existing gaps, and there are now practically no blanks. Fig. 23 shows a mature sal crop of fine quality in a high-level area. In the low-level sal forests much of the stock consists of mature trees in open crops, the ground being covered with much grass, chiefly *Saccharum Narenga*, and in places *Anthistiria gigantea* or *Imperata arundinacea* (see Fig. 24). Natural reproduction is more backward than in the high-level areas; in some places it is absent, but in many places it is making its way satisfactorily through the grass, sometimes with the aid of nurses such as *Holarrhena antidysenterica*, *Mallotus philippinensis*, and others. Here and there promising crops of sal saplings are establishing themselves, and in places there are dense pole crops in which the grass has been killed out. Throughout the greater part of the low-level areas the presence of so much inflammable grass is a constant source of danger, and when fires occur, as they do from time to time, much injury is done: the backwardness of reproduction in places may be attributed partly to the effects of fire.

A special and important type of forest in the low-level sal areas is that known as the *phanta*-belt type. It exists round the edges of the grassy blanks and represents former natural reproduction advancing into the savannahs. As a rule this belt varies from about 20 to 200 yds. in width. The crops are chiefly in the large pole stage; they are even-aged and are often of considerable density, in which case undergrowth is absent (Fig. 25), though a slight opening of the canopy produces a growth of grass, chiefly *Saccharum Narenga*. The trees are tall, straight, and well grown, and the sal is remarkably pure;

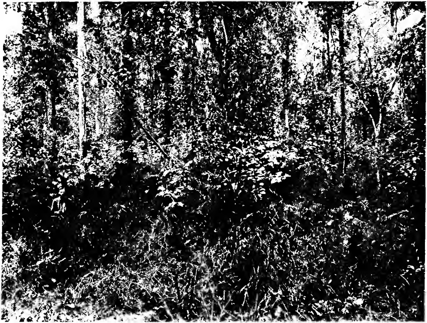

Fig. 27.—*Shorea robusta* high level forest of the Duars, with dense undergrowth; *Ulu* grass (*Pollinia ciliata*) and *Millettia auriculata* also plentiful. Buxa, Bengal.

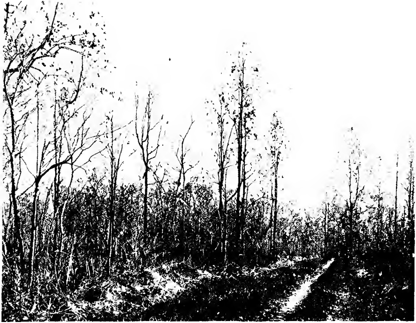

FIG. 28. *Shorea robusta* dry deciduous type of forest in the bhabar tract of Goalpara, Assam. Sal mixed chiefly with *Lagerstroemia parviflora*; appearance of forest in February.

a special feature is the almost entire absence of *Terminalia tomentosa* in the *phanta*-belt type.

The *damar*, or high bank separating the sal forests from the low alluvium, produces forest types of a particular kind, and the same applies to some extent to the less pronounced bank separating the high-level from the low-level sal forests. These banks are often much intersected by ravines, extending at times for a few hundred yards into the plateau and producing broken ground, the upper parts of which are much weathered and exposed to the desiccating influence of the sun. Here a poor dry open type of forest occurs, in which the sal is often mixed with *Diospyros tomentosa*: this type, which may be termed the upper *damar* type, appears to be commoner in Bahraich than in Kheri. It is most marked on stiff clayey soil, and is not found where the *damar* is not weathered or where the soil is porous and fertile; in the latter case the good drainage often produces a specially good quality of forest along the top of the *damar*. Another type occurs in the depressions or miniature valleys of the broken country along the *damar*. Here the silt is washed down from the higher ground during the rainy season, and a moist fertile soil is produced. The result is that these depressions are occupied by sal forest of very fine quality. The fertility of the soil is indicated by a dense undergrowth, often of *Clerodendron infortunatum*, and numerous climbers encircle the trees. This may be called the lower *damar* type; it is very limited in extent.

The good quality of the sal forests of North Kheri is perhaps most nearly approached by that of the Motipur forests of Bahraich, though both fall considerably short of the best qualities of forest in the Duars of Bengal and Assam. The South Kheri and Pilibhit forests are inferior in quality, though occasional good patches are met with, particularly in the northern parts of Pilibhit. Fig. 26 shows a poor open type of sal forest which is common in Pilibhit; the poor growth is due mainly to the stiff badly-drained soil, but frost and drought are partly responsible for lack of vigour. In Gonda the plains forests are represented by the Tikri forest, an outlying block in which the quality is only moderate, though the accessibility of this tract gives it special importance; this forest has been worked for many years as coppice-with-standards.

The Gorakhpur forests are, on the whole, only of moderate quality. The sal is, as a rule, remarkably pure: the height-growth is only moderate, though very fair growth is to be found along the high and well-drained ground in the neighbourhood of streams. Elsewhere the ground is somewhat low-lying, rice cultivation being practised in places up to the edge of the forest. The Gorakhpur forests are in the form of isolated blocks surrounded by cultivation. Their accessibility gives them a special value of their own, and in some of the blocks every stick, however small, is saleable. They lend themselves more than almost any other forests in India to an intensive system of management.

Bengal and Assam. In Bengal and Assam sal forests of a totally different type from those of the United Provinces are met with. The temperature is more equable, the rainfall greater and the humidity considerably higher. The absolute maximum shade temperature is only about 102° F. in the Duars; the absolute minimum in the same tract is about 40° F., and in some of the sal regions of Assam it is probably higher. Frost is unknown in these regions.

In the sub-Himalayan tract of Bengal the normal rainfall varies from 130 to 200 in. Farther east, in Kamrup, Darrang, and Nowgong, it varies from 65 to 100 in., while in the Garo hills it varies from 82 to 126 in. In these regions the sal encounters conditions of humidity which not only produce different types of forest from those found elsewhere, but also create factors which influence the establishment of natural reproduction in a different way. In the sub-Himalayan tract of Bengal and Assam the sal may be said to be growing under optimum conditions. Seedlings if grown in the open do not die back, but shoot up rapidly from the start. The subsequent growth of the trees is faster than in the western sub-Himalayan tract or in the central Indian region, and the quality of the sal forest is unequalled elsewhere, except perhaps in the valley type of the Singhbhum sal forests. In parts of the sub-Himalayan tract of the United Provinces the sal certainly attains large dimensions, but nowhere are there extensive tracts of sal forest, as in Bengal and Assam, where trees of such excellent height-growth are met with or where soundness is maintained to such a marked extent in trees of large size.

In western Bengal the sal is found in the Kurseong *tarai* and on the lower slopes of the hills up to 3,000 ft., ascending the Tista valley for some distance. The quality of the forest is, as a rule, excellent, the trees reaching large dimensions. As in the Duars, the dense undergrowth and the unfavourable soil conditions due to the excessive damp interfere with the natural reproduction of the sal. East of the Kurseong *tarai* the sal occurs throughout the Duars tract of Jalpaiguri, Buxa, and Goalpara, described in detail below, ascending the river valleys and the outer hills to about 3,000 ft. Thence the sal extends eastward, in suitable localities, through Kamrup, Darrang, and Nowgong. In Darrang the sal is at its eastern limit, and the total area of sal forest amounts to only about 700 acres, the best patch being in the Gorumari reserve, where the growth is good. Among the chief associates of the sal in Darrang are *Eugenia lanceaefolia*, *Gmelina arborea*, *Phyllanthus Emblica*, *Litsaea polyantha*, *Schima Wallichii*, *Stereospermum chelonoides*, *Sterculia villosa*, *Careya arborea*, *Adina cordifolia*, *Cinnamomum Cecidodaphne*, and *Bridelia retusa*.

In the Assam sal forests in general, as in the Duars, natural reproduction is a matter of difficulty, owing to the excessive damp, and the sal is likely to disappear in many places if special steps are not taken to regenerate it. In the Garo hills the sal attains very large dimensions, but the forests have suffered much from shifting cultivation. The same agency has destroyed much of the sal in the Khasi and Jaintia hills.

One of the most important sal tracts of the eastern sub-Himalayan region is that known as the Duars, occupying a stretch of country about 150 miles long, between the Tista and Manas rivers, with a maximum width of about 30 miles from the base of the hills southwards into the plains. The western or Bengal Duars, containing the Jalpaiguri and Buxa forests, lie west of the Sankos river, and the eastern Duars, containing the Goalpara forests of Assam, lie east of it. Sal occurs in the outer hills mixed with other species, but in the Duars proper two broad types of sal forest may be distinguished—the high-level or dry type, and the low-level or moist type. The high-level or dry type, which occurs in Buxa and Goalpara, occupies the dry *bhabar* tract on deep

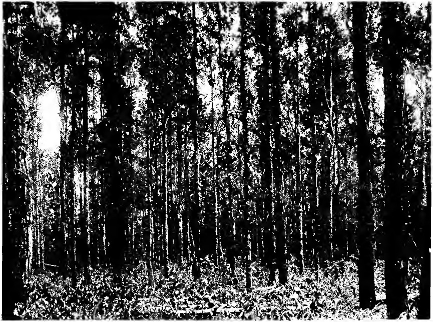

Fig. 20.—*Shorea robusta* forest of best quality, just thinned, Jalpaiguri, Bengal. Mean girth 2 ft. 3 in.; mean height 100 ft.; stems per acre after thinning 156; volume of standing crop 3,764 cub. ft.; volume removed in recent thinning 765 cub. ft.; estimated age 60 years.

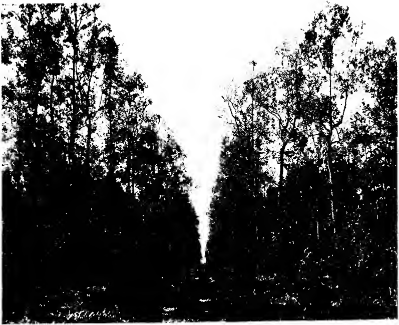

FIG. 30.—*Shorea robusta* low level forest of good quality, with fire-line, Goalpara, Assam.

boulder and gravel deposits stretching from the base of the hills to a maximum distance of about 12 miles from them: here the water-level is at a great depth. In Jalpaiguri this type is scarcely represented. The sal is, as a rule, of excellent quality. Among its commoner associates are *Lagerstroemia parviflora*, *Terminalia belerica*, *Sterculia villosa*, *Bombax malabaricum*, *Dillenia pentagyna*, *Cedrela Toona*, *Albizzia procera*, *Gmelina arborea*, *Stereospermum suaveolens*, *S. chelonoides*, *Premna* spp., and *Bauhinia* spp. The characteristic soil-covering is a dense growth of *sau* grass, *Pollinia ciliata*, Trin., a light feathery grass with a thin straggling wiry stem, which grows ordinarily to a height of 2 or 3 ft., but may climb through light undergrowth to a height of 5 or 6 ft., forming a dense mass which prevents sal seed from reaching the ground. This grass, which also occurs in the low-level type, though it is less abundant there, stands moderate shade, but is killed out by dense shade; it is encouraged by fire-protection. With it is commonly found an undergrowth of *Millettia auriculata*. Fig. 27 gives some idea of a typical *sau* grass area. Natural reproduction of sal in these areas is present only where the grass is scanty or absent. A dry and markedly deciduous sub-type of the high level forests occurs very locally in Goalpara. In this sub-type the sal reaches only moderate size, and its chief companions are *Lagerstroemia parviflora*, *Terminalia Chebula*, and *Phyllanthus Emblica*. The undergrowth either is absent or consists of a somewhat light growth of *Millettia auriculata*, *Dalbergia stipulacea*, and sometimes *Coffea bengalensis*; there is often present a scanty growth of grass, usually *Triraphis madagascariensis* var. *Zollingeri*, a grass ordinarily characteristic of dry miscellaneous forest. In this dry sub-type, which is shown in Fig. 28, natural reproduction of sal is usually good in spite of, and possibly in consequence of, fire-protection, a circumstance which is at variance with the conditions prevailing throughout the Duars sal forests as a whole.

The low-level or moist type of sal forest commences along the line of springs marking the southern limit of the dry *bhabar* tract. The forest is of a moist type, with a luxuriant and often evergreen undergrowth. The subsoil water-level is usually at no great depth. This type produces trees of large size and good shape where the drainage is good: in Goalpara particularly there are occasional patches of sal on badly-drained ground, where the growth is decidedly inferior. In Jalpaiguri the forest is of a moist type throughout, and on the well-drained high ground not far from streams the quality is extremely good, the boles being tall and cylindrical (see Fig. 29). Fig. 30 gives a typical view down a fire-line running through the Goalpara low-level sal forests. Most of the companions of the sal which occur in the dry or high-level type occur also in the moist type, but there is present a larger proportion of evergreen trees, such as *Amoora*, *Meliosma*, *Turpinia*, *Michelia Champaca*, *Schima Wallichii*, *Machilus*, and other lauraceous trees. There is a dense and largely evergreen undergrowth, which is described below.

The forests of the Duars, more particularly those of the moist type, furnish a striking example of the effects of continued fire-protection in altering the character of the forest and bringing it into such a condition as entirely to prevent the natural reproduction of the sal. It is an indisputable fact that the existing sal forests had their origin in burnt savannah lands. This is borne out from observations in burnt savannahs at the present day as well as from authentic records contained in forest working plans. The savannah lands are a characteristic feature of the Duars, particularly in Goalpara and Buxa; in Jalpaiguri they have now for the most part become filled up by tree-growth. Two broad types of savannahs may be distinguished, the low-level and the high-level savannahs. The former occupy low-lying moist ground containing a dense growth of such grasses as *Phragmites Karka*, Trin. (*narkal*), *Saccharum procerum*, Roxb. (*ekra*), *Erianthus elephantinus*, Hook. f., *Anthistiria gigantea*, Cav., *Saccharum spontaneum*, Linn., and others. On these tracts are scattered trees, chiefly *Albizzia procera*, *Bombax malabaricum*, *Bischoffia javanica*, *Eugenia operculata*, and *Butea frondosa*. In the riverain alluvial savannahs *Dalbergia Sissoo* is dominant. The low-level savannahs are unsuitable for the growth of sal. The high-level savannahs are typical sal-producing tracts, and occupy the better drained lands. The dominant grass of these tracts is *Saccharum Narenga*, Wall. (*bata*), which indicates conditions favourable for sal reproduction and growth. Other grasses on the high-level savannahs are *Saccharum arundinaceum*, Retz., *Arundinella Clarkei*, Hook., *Erianthus fastigiatus*, Nees, *Andropogon Nardus*, Linn., and *Imperata arundinacea*, Cyrill.; on ground sometimes not sufficiently well drained for sal occur *Saccharum spontaneum* and *Anthistiria gigantea*. The origin of the savannahs is not always clear, but there is no doubt that many of the high-level savannahs are the result of former clearings for cultivation; this is shown from the fact that former village sites, and bunds and boundaries of fields, are often still visible, while at the present time abandoned fields at once revert to savannah.

The savannahs become very dry by February, and if not specially fire-protected they burn at that time of year, producing fires of great severity. As long as annual fires occur these tracts persist in the form of grass-lands subject to the gradual invasion of fire-resisting trees such as sal, *Careya arborea*, *Dillenia pentagyna*, *Eugenia operculata*, *Bombax malabaricum*, and a few others. The establishment of the sal under these conditions is, it is true, gradual, seedlings and saplings being destroyed in quantity by the severe fires. Eventually, however, natural reproduction establishes itself by degrees, particularly where the saplings appear in clumps and commence to kill off the grass. Figs. 31, 32, and 33 show the manner in which the sal forests originate in these tracts.

Fire-protection was commenced in the Duars in 1872, and has been extended gradually since then. When a burnt savannah is fire-protected certain invasive trees and other plants quickly make their appearance. Of these the most characteristic is *Macaranga denticulata*, which is referred to below (p. 100). *Trema orientalis* and *Callicarpa arborea* are also forerunners of the subsequent tree forest, while the scitamineous plant *Alpinia Allughas* spreads rapidly. Where sal existed in quantity on the burnt savannah a more or less pure sal forest results, otherwise various deciduous trees and shrubs, such as *Sterculia villosa*, *Litsaea polyantha*, *Terminalia belerica*, *Gmelina arborea*, *Bombax malabaricum*, *Cedrela Toona*, *Lagerstroemia parviflora*, *Dillenia pentagyna*, *Careya arborea*, and many others, soon fill the gaps, the savannah grass is gradually killed out, and the result is a mixed deciduous fores , often with patches of sal in it. This, however, is only a stage in the progressive succession towards forest of a moister and more evergreen type. Wherever there is sufficient moisture *Alpinia Allughas* becomes invasive and forms dense masses, while *A. bracteata* appears in moist shady places (see Fig. 34). Species of *Leea*, *Vitis*, *Piper*, and other trailers and shrubs, together with ferns, make their appearance in quantity and form a dense soil-covering, above which appear masses of shrubs such as *Phlogacanthus thyrsiflorus*, *Viburnum Colebrookianum*, *Casearia Vareca*, *Micromelium pubescens*, and others (see Fig. 35). Evergreen shade-bearing trees such as *Amoora*, *Meliosma*, *Turpinia*, various Lauraceae, and others, commence to form a lower story, the larger species penetrating to the upper story. The whole mass is cemented together by a luxuriant growth of climbers such as *Spatholobus Roxburghii*, *Croton caudatus*, *Mucuna macrocarpa*, *Millettia auriculata*, *Mezoneuron cucullatum*, *Acacia Intsia* and *concinna*, *Bridelia stipularis*, and many others, while the damper places are often covered with a dense impenetrable mass of climbing and scrambling canes (see Fig. 36).

Such is the state to which the sal forests of the Duars, which originated in burnt savannah lands, in some cases possibly with an intervening stage of burnt deciduous forest, have been brought after a period of some thirty to forty years of fire-protection. A condition has been reached in which, as will be explained below, the establishment of natural reproduction of sal is out of the question, and the future of the species can be secured only by clear-felling followed by artificial reproduction.

Bihar and Orissa. In the sub-Himalayan tract of Bihar there are no regularly administered state forests. Mr. Haines [1] has given an interesting account of the forests of northern Champaran, in which he mentions that the greater part of the northern boundary of British territory borders the Nepal *tarai* at a considerable distance from the hills, but in the extreme north-west it recedes and is carried along a range of low hills in the north of the Ramnagar and Bettiah estates. These hills, with a strip of submontane land, are still covered with forest, while there is also a tract of forest, one to three miles wide, along the Gandak river in Bettiah, and a strip along the Nepal boundary to the east.

The forests are chiefly sal forests, intersected by strips of mixed forest on the newer alluvium and in the damper valleys. The sal attains its best growth in the *bhabar* at the foot of the hills, on the high banks of the older river valleys, and in the valleys themselves. In some of the more shady sal forests there is a gregarious growth of *Croton oblongifolius* on the ground. On the higher ground of the *bhabar* and on the hills the height-growth of the sal is usually poor; in these localities *Dillenia aurea* is a characteristic tree. On the hill ridges, at 1,000 to 1,600 ft., the sal is associated with *Pinus longifolia*. The hills themselves belong to the Siwalik system, and consist of fine-grained sandstone interbedded with occasional layers of water-worn stones. The sal forests have suffered from over-felling and from fire, while grazing further tends to keep down reproduction.

South of the Ganges the sal tracts of Bihar and Orissa lie mainly in the forest divisions of the Santal Parganas, Palmau, Chaibassa, Singhbhum,

---

[1] Ind. Forester, xliii (1917), p. 245.

Porahat, Sambalpur, Angul, and Puri. There are also considerable tracts in the Orissa Feudatory States.

The district forests of Hazaribagh contain a fairly large extent of sal, but they have suffered from all kinds of misuse in the past, and there are few trees of any size left. The sal forests of Palamau and Hazaribagh are somewhat poor in quality, being situated for the most part on shallow or unfertile soil. The rainfall varies from 40 to 54 in., but in the hot weather months the forests have to endure a high temperature and a low humidity owing to the prevalence of hot dry westerly winds from central India. In the winter frost damage is severe in places. In the Santal Parganas the sal is, on the whole, of better quality than in Palamau and Hazaribagh.

The forests of Sambalpur have suffered in the past from fire and resin-tapping, and large trees are mainly unsound and misshapen; former shifting cultivation has also created many blanks. The forests improve in quality towards the south. The chief companions of the sal are *Terminalia tomentosa*, *Pterocarpus Marsupium*, *Anogeissus latifolia*, *Diospyros Melanoxylon*, *Bassia latifolia*, *Dalbergia latifolia*, *Buchanania latifolia*, and *Eugenia Jambolana*; bamboos (*Dendrocalamus strictus*) are common in some of the poorer types of sal forest in hilly country. The sal is found chiefly in the valleys and on the lower slopes of hills, the upper and drier parts of which are covered with dry mixed forest or bamboos. The rock consists chiefly of sandstone, quartzite, shale, mica schist, and laterite. The rainfall averages about 56 in.

In Angul sal occupies the greater part of the reserved forests in the south and west of the district. Its density increases and its growth improves on proceeding from west to east. Trees of large size are not common, the stock being represented mainly by an advance growth of seedlings and saplings. In the high-lying valleys, at an elevation of about 1,100 to 1,500 ft., the growth is good, but in the low-lying valleys and plains the conditions are less favourable. Among the chief companions of the sal are *Pterocarpus Marsupium*, *Dalbergia latifolia*, *Ougeinia dalbergioides*, *Terminalia tomentosa*, *T. belerica*, *Adina cordifolia*, *Lagerstroemia parviflora*, *Anogeissus latifolia*, and *Stereospermum suaveolens*. The rock is chiefly gneiss and quartzite. The normal rainfall is about 50 to 55 in.

In Puri the northern and central forests, which are mainly on sandstone and laterite, consist for the most part of coppice growth varying from poor mixed forest to well-stocked forest of sal and *Xylia xylocarpa* poles. In the southern forests, which are for the most part on gneiss, giving a deep sandy loam in the valleys and on the lower slopes, the locality is much more favourable, and is capable of producing large-sized timber. The rainfall in the forest tracts varies from 50 to 60 in.

The forests of Singhbhum comprise by far the most important sal tracts in the province. The forest division of Singhbhum at one time included the forests of Kolhan and of the Porahat estate, but these have now been constituted separate divisions. A considerable portion of the Kolhan forests are on rather poor hilly ground, where the sal does not reach large dimensions, but towards the south-west they improve in quality and approach the type found in Singhbhum. The Porahat forests are likewise drier in type than those of Singhbhum, although in the valleys and on lower slopes they contain

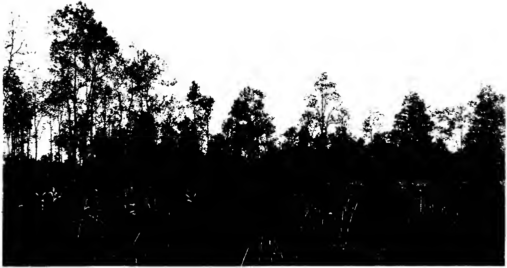

Fig. 36.—*Shorea robusta* pole crop established in burnt savannah (Goalpara, Assam); the grass is chiefly *Saccharum Narenga* recently burnt.

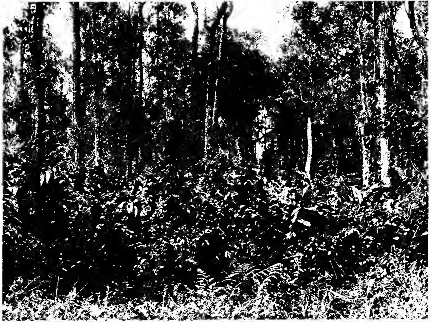

Fig. 31.—*Shorea robusta* forest with invasive evergreen undergrowth, chiefly *Alpinia*, induced by continued fire protection, Jalpaiguri, Bengal.

sal forest of decidedly good quality. The forests of Singhbhum proper, which are known as the Saranda forests, are situated in mountainous country at an elevation of 750 to 3,000 ft. The rocks are chiefly sub-metamorphic, consisting for the most part of quartzites, ferruginous schists, siliceous slates, and shales, while laterite is not uncommon. The rainfall varies from 50 to 65 in. Frost is very local in some of the high-lying plateaux, but the damage done by it is seldom severe. The quality of the forest varies greatly. In the valleys the forest is moist and the growth is excellent, the trees often reaching a height of 120 ft. On the hills a drier type of forest is met with in which the growth is poorer. On the drier ridges an open type of sal forest is common, in which the trees are stunted, misshapen, and often hollow. The poorest type of all is found on argillaceous rocks decomposing into a hard clay with quartz pebbles on the surface. The sal, if present, is very stunted, and is usually associated with *Gardenia gummifera*, *Buchanania latifolia*, *Terminalia tomentosa*, *Anogeissus latifolia*, and *Diospyros Melanoxylon*, while *Phoenix acaulis* frequently covers the ground. In the dry open types of hill forest the prevailing grass is the *sabai* (*Ischaemum angustifolium*, Hack.), which constitutes a valuable source of minor produce. Between the poorer hill types and the moist valley type there are various intermediate types occupying the hill-slopes and plateaux, and in all except the drier hill types the growth of the sal is decidedly good. A special feature of the Singhbhum sal forests is the excellence of the natural reproduction, which has established itself in profusion, particularly where heavy fellings were carried out from 1895 onwards.

Among the commonest companions of the sal are *Terminalia tomentosa*, *Pterocarpus Marsupium*, *Ougeinia dalbergioides*, *Bassia latifolia*. *Lagerstroemia parviflora*, *Adina cordifolia*, *Anogeissus latifolia*, *Buchanania latifolia*, and *Bauhinia retusa*.

Central India. There are considerable areas of sal forest to the south of the Kymore hills in Rewah state, but these have suffered a good deal from past felling and from resin-tapping.

Central Provinces. The important sal tracts of the Central Provinces are situated in the Jubbulpur, Mandla, Balaghat, Bilaspur, and Raipur districts. The Jubbulpur district is interesting in being the meeting-place of several geological formations. The existence of the sal, which is here at its western limit in the Peninsular region, is determined by the porous but hygroscopic Gondwana earthy sandstone, to which it is practically confined, and by the favourable rainfall, which is about 50 to 55 in. in the sal areas; teak, on the other hand, is confined to the trap and Vindhyan areas, chiefly sandstones, where the drainage is good. The sal is not of good quality, mature trees averaging scarcely 60 ft. in height, with a maximum height of 80 ft.; they seldom attain more than 5 ft. in girth, and are then usually unsound. Frost damage is severe in the cold weather, while in the hot season the temperature may reach 114° F. in the shade. Natural reproduction suffers much from frost.

In the Mandla district the sal forests of the Banjar valley are situated for the most part on the lower slopes of hills or in high valleys, chiefly at 1,800 to 2,000 ft., the hills being covered with mixed forest and the low ground being occupied by grass-lands. The quality of the sal forest varies. In favourable localities the growth is good, trees exceptionally attaining a height of 120 ft. and a girth of over 10 ft. : in poor localities they are stunted. The Motinala forests are much intersected by the remains of former shifting cultivation. The sal avoids the low ground, which is occupied by grass-lands. Frost does much damage, killing back sal reproduction. In the Khannat sal forests of South Mandla the quality varies much from place to place, but is on the whole inferior to that of the Banjar and Motinala forests. They are situated on laterite or on soil composed of a mixture of laterite and trap ; the sal avoids pure trap areas. On the slopes of the hills much of the sal forest originated in former temporary cultivation, and even-aged crops of poles, partly of seedling and partly of coppice origin, are the result. On the flat hill-tops with shallow soil a stunted type of sal forest is found. Among the chief companions of the sal in Mandla are *Terminalia tomentosa*, *Ougeinia dalbergioides*, *Pterocarpus Marsupium*, *Lagerstroemia parviflora*, *Anogeissus latifolia*, *Adina cordifolia*, *Stereospermum suaveolens*, and *Buchanania latifolia*. The rainfall varies from 50 to 60 in.

In the Balaghat district there are two main sal areas, Raigarh and Baihar. In the former the rock consists of laterite and trap, but the sal avoids the pure trap ; in the latter the rock is largely gneiss. The sal occurs on low hills, on the lower slopes of high hills, and on the undulating portions of valleys. In Raigarh it occurs chiefly at an elevation of 2,000 to 2,500 ft., the lower ground being occupied by grass-lands. In Baihar the upper limit of the sal is 2,000 ft., and the sal forest is much interspersed with grass-lands. The sal is almost pure except where it merges into mixed forest, in which case it forms only a small portion of the stock : in Baihar it is frequently mixed with bamboos (*Dendrocalamus strictus*). The sal forest varies much in quality, but in favourable localities trees of large size are produced. In some localities frost damage is severe, young sal being killed back annually and poles also suffering much. The rainfall varies from 50 to 65 in.

In Bilaspur the most important sal forests are those of Lormi, Kanhai, and Shirmal. In Lormi the best sal is found in the valleys and on the lower slopes of the hills : the principal rocks of the sal areas are schists of the Dharwar series. The best sal trees are often found mixed with large *Terminalia tomentosa* on deep moist alluvial soil near some of the rivers. A type occurring along the base of the hills consists of a good crop of fair-sized sal standing over a dense crop of bamboos, which retard sal reproduction. The Kanhai sal forests are somewhat similar to those of Lormi. The Shirmal sal forests produce timber of moderate size, but not so large on the whole as in Lormi. In the Bilaspur sal forests frost damage is often severe. The rainfall is about 50 in. Sal also occurs in the Chita-Pandaria forests on shallow soil overlying limestone ; it is found only in small quantities, however, and the growth is poor. The Sonakhan sal forests in the north of the Raipur district are included in the Bilaspur forest division. They are situated on metamorphic and submetamorphic rocks, ceasing abruptly at the Cuddapah sandstone belt and avoiding limestone.

In the Raipur district the Sihawa forests constitute a promising tract of sal, although the trees are as yet immature. In the northern part of the tract sal occurs only in scattered patches, but farther south it increases in quantity, and forms large pure masses. The rainfall is slightly over 50 in. Sal forests also occur in the south-east of the Laun range, the best of them being in the Kantranala reserve: elsewhere the sal is found in straggling belts and patches or in the form of isolated trees in dry forest. Both the Sihawa and the Laun sal forests are found on metamorphic rocks.

Madras. In the Madras Presidency sal occurs chiefly in Ganjam, and to a limited extent in Jeypore and in the Palkonda range of Vizagapatam. In the Ganjam district sal is found in the Goomsur forests. The rock is largely gneiss, with metamorphosed sandstone in places. An indurated ferruginous red clay caps many of the low hills, and the sal growth here is poor, the soil being not sufficiently porous. In the western part of the Goomsur forests (Surada range) the country is chiefly hilly, the sal occupying the slopes of the hills and growing to a very fair size in favourable localities. To the east (Bugnda range) the country is flatter, and the sal grows at a lower elevation on the whole. In the forests of the plains, on alluvial ground, the sal is purer but of smaller size than in the hill forests. The plains forests have been subjected to much ill treatment in the past, and the stock consists largely of coppice and pollard growth. The chief companions of the sal are *Terminalia tomentosa*, *Pterocarpus Marsupium*, *Lagerstroemia parvifolia*, *Dalbergia latifolia*, *Adina cordifolia*, and *Diospyros Melanoxylon*. Where the soil becomes less favourable there is a larger mixture of *Cleistanthus collinus*, *Soymida febrifuga*, *Dillenia pentagyna*, *Buchanania latifolia*, *Phyllanthus Emblica*, and *Odina Wodier*. In Ganjam the sal experiences the north-east as well as the south-west monsoon. The rainfall is about 50 in., of which the south-west monsoon, July to September, contributes 30 in., and the north-east monsoon, October to December, 15 in., the remaining 5 in. falling from January to June.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The leaves commence turning yellow and falling from January to March. In dry seasons and in dry localities leaf-shedding takes place earlier and is more complete than in wet seasons and in moist localities; in the latter the leaves may have hardly commenced to fall by March. For a short time, from February to April, according to locality and season, the foliage of the trees is somewhat scanty: only in dry localities, however, do the trees become quite leafless for a short time. The new leaves and shoots appear from February to May according to locality and season. The young leaves are tender, reddish, and shining; they soon turn to a fresh delicate green. Where the old foliage is defoliated by insects early in the year the new shoots appear earlier than usual. Sometimes two separate flushes of new leaves appear in one season. A second flush may appear after defoliation, but it may also be produced in exceptionally dry seasons after a partial shedding of the first flush.

The flower-buds as a rule first become visible in February, but in early seasons they may appear in the latter part of January. The small whitish flowers are in large lax terminal or axillary racemose panicles, covered with a whitish pubescence (see Fig. 37). They are fully out from the end of February to well on in April, according to locality and season. At this time the trees are partially leafless, and when covered with masses of whitish blossom they are a striking sight, particularly in years of extensive and profuse flowering, when the whole forest is clothed in a mantle of white. Fig. 39

shows a sal tree in flower. The petals soon fall like snow, covering the ground beneath and around the trees.

The young fruits form rapidly, and their reddish to pale yellowish-green colour gives a characteristic hue to those trees which bear them in quantity. The fruits (Figs. 38 and 40, *a*) are 0·5–0·6 in. long by 0·4 in. in diameter, ovoid, acute, whitish pubescent, indehiscent, surrounded by the segments of the calyx enlarged into five rather unequal wings which are 2–3 in. long, obtuse, spathulate, contracted at the base, brown when dry. About 350–420 fruits weigh 1 lb. The fruits ripen in June, and fall as soon as they ripen; ordinary breezes do not carry them more than about 50 to 100 yards from the tree, but strong winds may convey them to a considerable distance. If moisture conditions are favourable the seed germinates soon after falling, and germination may even begin on the tree. Sound fresh seed has a high percentage of fertility, but the seed rapidly loses its vitality, and under ordinary conditions will not keep fertile for many days. Drought is the chief cause of mortality, and if care is taken to keep the seeds cool and prevent their dying they may retain their vitality for a few weeks. Seed sent by Mr. Hole from Dehra Dun to Singapore, which was twenty-four days in transit, produced a good stock of healthy seedlings. An experiment was carried out at Dehra Dun in 1913 to ascertain the length of time during which seed would remain fertile if kept under different conditions. Fresh seed gave a fertility of 90 per cent., and seed from the same sample stored under different conditions gave the following results:

Shorea robusta: germination tests of seed kept under different conditions.

	Percentage of fertility under different methods of storage.				
Number of days after collection.	Loose in basket indoors. Per cent.	Loose in basket in shade out of doors. Per cent.	Packed in dry earth. Per cent.	Packed in sawdust. Per cent.	Packed in lime. Per cent.
7	50	90	50	55	90
15	10	25	25	50	40
20	10	nil	30	40	40
27	nil	nil	5	nil	45

Sawdust was found to check germination, but lime did not have this effect, the seed germinating and producing taproots 3 in. long and shoots 2 in. long, though the young plants kept in perfectly good condition in the lime, some remaining so for two months or more. Lime would thus appear to be a suitable medium for packing seed to send to a distance.

A note[1] which I published in 1912 gave the results of a large number of germination tests carried out in different localities, the main object of which was to ascertain to what extent the fertility of sal seed is affected by the size and condition of the trees producing it and by the locality and the type and density of forest in which the trees grow; the question is of importance in connexion with the retention of seed-bearers. The quantity of seed produced under different conditions was not a subject of investigation. The chief results obtained were as follows:

(*a*) The size of the tree has no apparent effect on the fertility of the seed.

---

[1] Note on some Germination Tests with Sal Seed, For. Bull. No. 8, 1912.

(*b*) In some localities fertile seed begins to be produced by trees under 1½ ft. in girth, the minimum girth recorded being 7 in.; in other localities no seed was obtainable from trees of this size.

(*c*) The average percentage of fertility is maintained in trees of large girth, namely, 15 ft. and over.

(*d*) Factors which were not proved to have any effect on the fertility of the seed were (i) the soundness or unsoundness of the seed-bearers, and (ii) the locality, soil, aspect, and type and density of forest in which the seed-bearers grow.

(*e*) The time of collection possibly has an influence on the fertility of sal seed, the most fertile seed being obtained at the middle of the fruiting period and less fertile seed being obtained at its beginning and end; further experiments, however, are necessary before any definite conclusion can be arrived at on this point.

As regards the size of the trees which produce fertile seed, it may be noted further that in 1910, a favourable seed-year in the Dehra Dun forests, abundant seedlings were observed to have sprung up round pole forest where the largest trees were not more than 2 ft. in girth and 40 ft. in height. In the dry stunted forests of the Siwalik hills numerous seedlings were found where none of the seed-bearers exceeded 22 in. in girth.

The fertility of seed from coppice-shoots was at one time called in question. All doubt on the subject, however, has been set at rest by tests carried out in different localities. A series of experiments carried out in 1905 and previous years in Bahraich, United Provinces, showed that seed from coppice germinates well; in some cases there was no appreciable difference between its fertility and that of seed from seedling trees, while in other cases seed from seedling trees gave better results than that from coppice-shoots. Tests carried out in 1906 in Gonda, United Provinces, with seed from coppice-shoots of various sizes showed an average fertility of 70 per cent. Mr. C. E. C. Fischer[1] has recorded the results of germination tests in Ganjam, Madras, in which 170 seeds each were tested from coppice-shoots and standards. The result showed a fertility of 40 per cent. for the seed from coppice-shoots as against 48 per cent. for seed from standards: there was no difference in the vigour of the resulting seedlings.

In most localities good seed-years are of fairly frequent occurrence, while occasionally the seeding is remarkably gregarious and profuse. When storms, hail, or strong dry winds occur from March to June the flowers and immature fruits, whose peduncles are very tender, may be blown or knocked down in quantity, and an otherwise promising seed-crop may be entirely destroyed. Insects are at times also responsible for the destruction of a good deal of seed. The statement on p. 80, showing the nature of the seed-year in different localities and years, has been compiled from such records as exist: these are not always very accurate or precise, but the statement may be taken as approximately correct on the whole.

---

[1] Ind. Forester, xxx (1904), p. 198.

Shorea robusta: records of seed-years in different localities.

Year.	United Provinces.								Bengal.					Assam.					Bihar and Orissa.						
	Dehra Dun.	Ramnagar.	Haldwani.	Pilibhit.	Kheri.	Bahraich.	Gonda.	Gorakhpur.	Darjeeling.	Kurseong.	Tista.	Jalpaiguri.	Buxa.	Goalpara.	Kamrup.	Darrang.	Nowgong.	Garo Hills.	Santal Parganas.	Palamau.	Singhbhum.	Chaibassa (Kolhan).	Sambalpur.	Angul.	Puri.
1881	P	..	..	..	..	A	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
1882	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
1883	A	..	..	..	..	A	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
1884	P	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
1885	A	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
1886	M	..	..	..	..	A	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
1887	..	A	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
1888	M	M	..	A	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
1889	M	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
1890	A	..	..	A	..	..	A	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
1891	A	..	..	..	A	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
1892	P	P	..	A	A	A	A	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
1893	P	M	M	..	P	P	M	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
1894	M	A	A	..	P	..	P	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
1895	P	P	A	P	P	P	M	..	..	..	..	A	..	..	..	..	..	..	..	..	..	..	..	..	..
1896	A	..	M	A	A	A	..	..	..	..	..	A	..	..	..	..	..	..	..	..	..	..	..	..	..
1897	M	P	M	..	M	..	P	P	..	..	..	M	..	..	..	..	..	..	..	..	..	..	..	..	..
1898	M	M	M	P	A	M	A	P	..	..	..	P	..	..	..	..	..	..	..	..	..	..	..	..	..
1899	M	A	A	P	A	P	P	..	..	..	..	A	..	..	..	..	A	..	..	..	..	..	..	..	..
1900	A	A	A	A	A	A	A	A	..	..	..	P	..	..	..	..	P	..	..	..	..	..	..	..	..
1901	M	M	M	P	P	..	..	..	..	..	..	..	A	A	A	..	A	A	..	..	..	..	..	..	..
1902	M	P	M	P	P	..	M	..	..	..	..	..	P	P	..	..	P	P	..	..	..	..	..	..	..
1903	M	A	A	A	M	A	M	..	..	..	..	..	..	A	A	..	A	A	..	..	..	..	..	..	..
1904	P	P	M	M	..	P	P	..	..	..	..	..	..	P	A	A	A	P	..	..	..	..	..	..	..
1905	P	P	P	P	P	P	P	P	..	..	..	A	..	P	A	..	..	P	..	..	..	..	..	..	..
1906	A	..	A	A	A	..	M	..	..	A	A	A	..	..	A	..	A	M	M	..	P	..	..	A	..
1907	M	P	P	M	..	..	A	..	..	A	..	A	A	..	A	..	A	..	A	..	A	M	A	A	A
1908	P	P	P	P	P	P	P	P	..	..	..	P	P	P	M	..	M	..	M	A	A	..	A	..	M
1909	P	P	M	..	P	..	M	..	..	A	A	A	A	A	A	..	A	A	A	A	A	..	A	..	M
1910	A	A	A	A	A	A	A	A	..	..	..	P	P	P	M	..	P	M	M	..	M	..	A	A	..
1911	P	..	P	P	P	..	..	..	..	A	..	..	A	A	A	..	A	A	..	..	..	..	..	..	..
1912	P	P	P	P	P	P	P	P	P	P	A	P	P	P	P	..	P	P	A	M	A	A	A	A	A
1913	A	A	A	A	A	A	A	A	A	A	A	A	A	P	A	A	A	A	A	A	A	A	A	A	A
1914	..	..	P	P	P	P	P	P	P	P	P	P	P	..	..	..	..	..	..	..	..	..	..	..	..
1915	..	..	A	A	A	A	A	A	..	A	A	A	A	A	A	A	A	A	..	..	..	..	..	A	..
1916	P	P	P	P	P	P	P	P	P	P	P	P	P	..	..	..	..	..	P	P	P	P	P	P	P

A = abundant or good. M = moderate. P = poor.

The foregoing statement shows in a remarkable manner how widespread a good or a bad seed-year may be in certain years. In the United Provinces the year 1910, and throughout the greater part of the sub-Himalayan tract the years 1913 and 1915, will be remembered as years of profuse seeding, while in the intermediate years the seed-crop was a failure. Apart from injury to the seed-crop by storms and winds, climatic conditions appear to be responsible at times for the state of the seed-year. In the spring of 1905 the forests of the United Provinces were much damaged by an abnormally severe frost, and the failure of the seed-crop was reported at the time to be due to this cause. The year 1908 in the United Provinces, and the year 1916 in Bihar and Orissa, in which the seed-crops failed, followed seasons of abnormal drought.

GERMINATION (Fig. 40, *b–e*). Hypogeous. The radicle emerges towards the apex of the fruit and descends rapidly, soon forming a taproot. The cotyledonary petioles meanwhile elongate considerably, carrying the plumule free of the seed and enabling the young shoot to make its way upwards. The fleshy cotyledons remain within the fruit.

THE SEEDLING (Fig. 40).

Roots: primary root long, thick, terete, tapering, woody: lateral roots fibrous, long and numerous if growing in water or in moist layers of dead leaves, shorter and less numerous in mineral soil. *Hypocotyl* scarcely distinguishable from root, subterranean. *Cotyledons* appearing to be opposite, but shown by the position of the axillary buds, which are hidden by the united bases of the cotyledonary petioles, to be frequently alternate: petiole 1·2–1·8 in. long, flattened and channelled on inner side, bases of petioles united in a tube round the stem: lamina 0·4–0·5 in. by 0·5–0·6 in., thick, fleshy, 2-lobed, pink or reddish green. *Stem* erect, wiry, reddish in young stage, turning green and later greenish brown, very finely pubescent or glabrescent; first internode (below first pair of foliage leaves) 2·8–5 in. long, slightly compressed, subsequent internodes much shorter, 0·5–1·5 in. long. *Leaves* simple, first pair opposite, subsequent leaves alternate. Stipules 0·1 in. long, caducous. Petiole 0·2–0·25 in. long. Lamina 2·3–3·5 in. by 1·2–2·3 in., ovate-oblong, acuminate. base rounded or cordate, entire, subcoriaceous, glabrous, dark green and shining above, slightly paler beneath, young leaves often reddish.

The first pair of opposite foliage leaves are very characteristic, and seedlings of the first year can usually be distinguished with certainty by their presence, though they may persist through part of the second season.

Stem development. The stems of sal seedlings are at first thin and whippy, but a stage is eventually reached when they become thickened, with a smooth cortex and an almost fleshy appearance. From this stage onwards growth is more rapid than it was previously, and the seedling may be considered to have established itself and to be ready to shoot upwards. Before long the smooth cortex begins to crack and rough bark to form, when the plant may be considered to have reached the sapling stage. The rate of development varies greatly according to local conditions. As an example of rapid growth in seedlings an instance may be quoted of a nursery plot at Mendabari in the Buxa district, Bengal, in which seed was sown in June 1911. In January 1915 the resulting seedlings, which were then 3½ years old and formed a dense clump, were thinned out: the forty-three plants which remained had a mean girth and height of 5·5 in. and 14 ft., and a maximum girth and height of 8·4 in. and 16 ft. respectively. On several of the plants rough bark was already forming on the lower part of the stem. The plot in question is shown in Fig. 41, and subsequent measurements made in it are recorded below (p. 123). Such rapid growth, however, is possible only under specially favourable conditions, such as those which obtain in the Bengal Duars. In northern India healthy natural forest seedlings usually attain a height of about 4–7 in. and have two to four leaves by the end of the first season. Growth as a rule ceases about October, and the new season's growth begins about March–April. At Dehra Dun vigorous nursery-raised seedlings have attained maximum heights of 2½ and 4 ft. by the end of the second and third seasons respectively, the larger plants in the third season having developed thick stems. Mr. Hole [1] records the following measurements of vigorous artificially-grown seedlings at Dehra Dun :

56 seedlings 1 year old had a mean height of 13·6 in. and a maximum height of 23·5 in.

83 seedlings 2 years old had a mean height of 26 in. and a maximum height of 76 in.

Natural forest seedlings show development which is not only much slower but which, in the great majority of cases, is retarded owing to the habit of dying back described below.

Root development. Under normal conditions a healthy sal seedling quickly develops a long stout taproot, which may reach a length of 3 ft. by the end of the first season, though this is well above the average. Subsequent elongation and thickening of the taproot is also very marked. Under conditions unfavourable to the development of the root-system the taproot may show very feeble development or may be almost absent. A normal well-developed taproot usually has a fair number of comparatively short fibrous lateral roots on it, but the energy of the plant is concentrated mainly on the taproot, on the vigour of which the young plant has to depend for its ultimate survival. Under abnormal conditions large numbers of long lateral rootlets are produced, for example in water-cultures or where the roots run horizontally between layers of moist leaves without penetrating to the mineral soil. Mr. Hole [2] has shown that the development of the taproot is much poorer in seedlings grown under shade than in those grown in the open : this fact is of great importance where the establishment of reproduction is concerned.

Dying back. The dying back or complete dying off of sal seedlings in the forest is a phenomenon with which all who are acquainted with this tree are familiar. After a good seed-year, and with the timely commencement of the monsoon rains, the sal seed germinates readily, and thousands of seedlings are soon found covering the ground. The promise of abundant reproduction, however, is doomed to disappointment, for except under the most favourable conditions before a year is over the number of seedlings is greatly reduced by wholesale dying off, though a proportion may survive, the stem dying down and new shoots being sent up the following season. This dying back may consist of the death of the whole stem, a new shoot being produced from buds in the axils of the cotyledons, or of only a portion of the stem, growth

[1] Ind. For. Records, vol. v, pt. iv, p. 44.

[2] *loc. cit.*, pp. 56, 64.

being carried on by new shoots produced from axillary buds at different points on the stem. Dying back with subsequent recovery takes place when the taproot has developed with sufficient vigour to withstand the adverse influences which cause the death of the aerial portion of the plant.

Some years ago a large number of plots were laid out in many different parts of India, in places where natural sal seedlings had appeared in abundance after good seed-years. These plots were kept under observation for a series of years, and the results told a similar tale in each case. At the best the number of seedlings diminished steadily each year, while under less favourable conditions there was wholesale dying off, not a single plant surviving: where conditions were favourable a few seedlings in each plot ultimately established themselves, sometimes after dying back several times; but taking the plots as a whole the mortality was enormous.

The death or dying back of sal seedlings takes place at different times of the year, and, as will be seen later, may be due to various causes. In the rainy season mortality is very high. In dry localities the seedlings may survive the rains but die down in the ensuing dry season, suggesting drought as the cause. In frosty localities they are killed down by frost in the winter, and send up new shoots at the commencement of the following growing season. Although large numbers of seedlings ultimately succumb after a more or less lengthy struggle, during which they may die back several times, it is noteworthy that during the struggle a great development of the taproot takes place steadily, and that the struggle is essentially an underground one. Plants only a few inches high, which have died back repeatedly, if dug up will be found to have greatly thickened root-stocks which penetrate to a considerable depth. Those plants which at last succeed in establishing themselves cease to die back and begin to produce thick shoots: from this time onwards their upward growth takes place normally, and before long they begin to produce rough bark and may be said to have reached the sapling stage. The time taken in the process varies according to local conditions. In a favourable case recorded above the sapling stage was reached within 3½ years. In the case of natural forest seedlings under conditions usually obtaining in north-western and peninsular India, the time occupied is very much longer, possibly at least ten years, and in many cases considerably more.

The dying back of seedlings under adverse conditions is not peculiar to the sal, but is seen in various other Indian species. In the case of the sal, although so prevalent it must be regarded as an abnormal process induced by external conditions and not as an inherent characteristic. In the Bengal Duars, where optimum conditions are approached, natural sal seedlings growing in the open do not ordinarily die back but shoot up with rapid growth straight from the seed. Seedlings raised artificially in nurseries in many localities, if carefully tended, do not die back but develop strong shoots at an early age. In the forests near Dehra Dun Mr. Hole's experiments, described below, have shown that favourable conditions can be produced under which seedlings do not die back, although wholesale dying back of natural seedlings takes place in the immediate vicinity. Even in northern India many natural forest seedlings do not die back, though their stem development may be retarded for years while the taproot is establishing itself.

The phenomenon of dying back, with subsequent establishment, gave rise at one time to a theory as to its cause which deserves some consideration. According to this theory the sal seedling is unable to establish itself and to start upward growth until its taproot has penetrated downwards to the permanent subsoil water-table: only then are supplies of water available sufficient to prevent further dying back and to enable upward growth to commence. This theory, if it is held to be of general application, is at once refuted by the fact that under favourable conditions sal seedlings do not die back, but may commence vigorous upward growth when their taproots are not many feet long in localities where the subsoil water-table is at a great depth, for instance in the *bhabar* tract of the Bengal Duars or, in the case of artificially-raised seedlings, in the neighbourhood of Dehra Dun. The fact is, as Mr. Hole has shown, that, other conditions being favourable, sal seedlings will survive and develop normally where the moisture in the soil does not fall below 3 per cent. in sand and 10 per cent. in loam.

The question of mortality among sal seedlings has been the subject of exhaustive study by Mr. R. S. Hole, the results of whose researches have been of the greatest value in determining the chief causes of death and in indicating the measures necessary to prevent mortality. His experiments, which were carried out at and in the neighbourhood of Dehra Dun, were commenced in 1909 and have extended over a series of years. They not only embraced pot-cultures, water-cultures, and work in the experimental garden, but also extended to the local sal forests, where highly interesting results were obtained in numerous control plots. The experiments have been described in some detail in the *Indian Forest Records*,[1] and it will not be possible here to do more than recapitulate briefly the principal results. They are as follows:

1. *Primary soil factors.* The primary factors which determine whether or not sal seedlings can thrive on a particular soil are (i) the water-content of the soil, and (ii) the aeration of the soil. Provided these are suitable sal seedlings will grow well on soils of widely different chemical and physical composition and will show little, if any, dying back.
2. *Primary causes of mortality.* Omitting cases of damage by frost, which are local, and injury by animals, insects, &c., two factors have been found to be of outstanding and primary importance in causing the death or dying back of sal seedlings: (i) an injurious soil factor which comes into operation in the rainy season, especially in the months of July and August; and (ii) drought, which causes widespread damage during the season of short rainfall from September to June. Of these two factors the former is the more important, since those plants which have developed vigorously during the rains are able to resist the subsequent damage from drought owing to their strong deep-going root-system, whereas weakly plants with a poorly developed root-system quickly succumb after the rainy season is over.
3. *Soil water-content.* Seedlings die or die back from drought when the water-content of the soil in contact with their roots falls to 3 per cent. and below in sand or sandy loam. Owing to the rapidity with which sand parts with its moisture, under similar conditions of environment and water-supply seedlings die or die back from drought most rapidly on sand, less

---

[1] Ind. For. Records, vol. v, pt. iv. Oecology of sal. I. Soil-composition, soil-moisture, soil-aeration (1914). II. Seedling reproduction in natural forests and its improvement (1916). III Soil-aeration and water-cultures (1916).

quickly on loam, and most slowly on leaf-mould. It is not necessary for the healthy development of sal seedlings that the roots should reach the permanently saturated layers of the water-table: a 3 ft. layer of forest loam is, in years of heavy rainfall, able to retain sufficient moisture for the healthy development of sal seedlings, even when separated from the subsoil by a waterless layer of stones.

4. *Injurious soil factor*. In years of heavy rainfall germination is better on sand than on water-retaining leaf-mould and loam. The death or dying back of seedlings during the rains is caused by an injurious soil factor due chiefly, if not entirely, to bad aeration. This injurious factor is operative mainly in non-porous soils in which the water-content is high and the water-free air space is small, and through which water does not percolate freely but remains for some time *in situ*. In such soils the mortality may be as high as 100 per cent. The injurious factor is aggravated by the presence of organic matter such as dead sal leaves: it is also aggravated by consolidation of the soil through mechanical pressure, the pore-space being thereby reduced. The injurious action is correlated with an accumulation of carbon dioxide in the soil-solution and a low oxygen-content, the latter indicating a condition adverse to free root-respiration. It is probable, though further proof is necessary, that the injurious action may be caused in part by the presence of one or more toxic substances in the soil which are directly poisonous to the roots. The toxic substance or substances are possibly in part secreted by the plant roots or by soil organisms, but they are probably produced mainly as a result of the decomposition of the organic matter in the soil: they can accumulate or become injurious only under conditions of bad aeration coupled with a high water-content, whereas they are rapidly dissipated and rendered innocuous by good aeration. That the injurious effects of bad aeration are not due to water as such, is proved by the fact that sal seedlings can be grown successfully in water-cultures. Bad soil-aeration retards root development and results in a superficial root-system: it is accompanied by a more or less extensive dying and rotting of the roots, which is worst towards the root apex.

5. *Effect of forest cover on other factors*. In the open with full overhead light but with light side shade and a light intensity of 0·3 to 0·7 (Clements's photometer) the percentage of seedlings which germinate and survive is decidedly higher, and the percentage which die back is decidedly lower, than in the shade of the forest with a light intensity of 0·05 to 0·08. The root development in particular is much better in the open than under shade (14·1 and 20·9 in. in two plots in the open, as against 4·7 and 7·3 in. in two plots in the shade). The inferior growth of sal seedlings in the shade of the forest is due primarily not to deficient light, to unsuitable air-temperature or air-humidity, or to a deficient supply of available plant food, but to an injurious soil factor. In the rains the inferior results in the shade are connected with the decomposition of humus, and are due to bad soil-aeration caused by a higher percentage of organic matter and water, a smaller water-free air space, and probably an accumulation of toxic decomposition products. In the dry season the high percentage of mortality in the shade is due to drought, and is the direct consequence of the poor root development during the rains. In May 1913 it was found that as a rule the moisture-content of the soil, both in the shade and in the open, approached the death limit in the surface layers, but increased on proceeding downwards; it was also found that the moisture percentage below 9 in. in depth was higher in the open than under the shade of the forest close by. This emphasizes the advantage of a strong root development during the first growing season, that is the rainy season.

6. *Remedies for adverse conditions*. In order to ensure the survival of seedlings in the ensuing dry season, it is necessary to promote vigorous growth during the rainy season. The injurious soil factors can be readily eliminated and vigorous growth stimulated by aerating the soil, that is by digging it up,

and in loam by removing the dead leaves by sweeping or burning. Sowings on a fire-line have demonstrated that continued annual firing has no obvious injurious effect on the soil so far as its capacity to produce healthy seedlings is concerned. In sand, on the other hand, a mixture of dead leaves may be beneficial rather than otherwise, in assisting the retention of moisture. Vigorous growth of seedlings is further stimulated by the complete removal of the overhead canopy, side shade being retained in order to protect the seedlings from frost and to keep the soil moist during the dry season. In the Dehra Dun forests practically ideal development of sal seedlings can be secured by clear-felling in patches or strips not more than 100 ft. wide and preferably not more than 60 ft. wide, removing dead leaves, digging up the ground, artificially sowing sal seeds, and weeding during the first rains.

Mr. Hole's experiments have, it is true, been confined to one particular locality, namely, the Dehra Dun neighbourhood, where the normal rainfall is about 85 in. and the forests are of a fairly moist rather than of a dry type. In the very moist type of sal forest met with in the Bengal Duars seedlings will not survive on narrow cleared lines through the forest, owing to the excessive dampness of the soil and the adverse factors induced by it. Nevertheless, these experiments have covered a range wide enough to demonstrate the main causes of mortality in sal seedlings and to indicate the measures necessary to counteract the adverse factors: the details of these measures must naturally vary with local conditions. The further application of Mr. Hole's results can best be dealt with under 'natural reproduction' and 'silvicultural treatment'.

Other causes of injury. Among animals, pigs and porcupines, especially the latter, do a good deal of damage to sal seedlings in some localities, and rats also do much damage in grassy areas by gnawing through the taproot and the base of the stem. The seedlings are readily browsed by deer and cattle. They are subject to various forms of injury by insects, perhaps the most serious being the biting through of the taproot, probably by crickets. Sal seedlings are somewhat frost-tender, but have good power of recovery from the effects of frost. In localities subject to frost they are frequently killed back year after year; this occurs chiefly in grassy tracts. Protective measures are given below under 'natural reproduction' (pp. 97, 98).

SILVICULTURAL CHARACTERS. *Light.* Although the sal is able to persist under moderate shade, it is, strictly speaking, a light-demander and not a shade-bearer, its best development being secured by the admission of complete overhead light from the earliest stage, though as already stated young plants require side protection from frost and drought where these are factors to be considered. In dense pole crops numerous small whippy shoots are often found in abundance; these might be mistaken for seedlings, but on examination they are often found to spring from the bases of saplings which have been killed in the struggle for existence. As long as the cover remains unbroken these shoots continue in their whippy form until they eventually die, but if the cover is broken one or more thick shoots are sent up from each stool, and these eventually establish themselves.

Root-system. Normally the sal produces a long stout taproot of great length, which reaches down to strata moist enough to supply the water requirements of the tree, and in the plains can, as a rule, be traced down to the permanent subsoil water-level. In addition stout lateral roots are produced at no great depth below the surface, while deeper down are found numerous fibrous lateral nutrition rootlets ramifying in all directions where there is sufficient moisture. In an investigation in 1913 into the nature of the subsoil in sample plots, interesting observations were made during the digging of six wells in forest on old alluvium in the Gorakhpur district. It was found that stout lateral roots were produced at a depth of 1 to 8 ft., the actual depth varying in different places; the soil in which these roots were found varied, but as a rule the roots were nearer the surface in clayey than in sandy soils. Below these roots, at a depth varying from 8 to 14 ft., and in some cases extending down to water-level, were numerous fibrous lateral rootlets, always in moist strata, the soil varying from pure sand to pure stiff clay. The depth of the water-level varied from 12 ft. 9 in. to 18 ft. 6 in. In one case the soil throughout was a very stiff clay, and the trees were gnarled and stunted. Here the fibrous rootlets were at a depth of 11 to 14 ft.; they were unable to pierce the stiff clay, but every fracture in the clay revealed masses of minute rootlets flattened out in the fissures. Below 14 ft. the clay was too moist and pliant to allow of fissures, and sal rootlets were absent. It is not unlikely that the fact that in stiff clay the rootlets are confined to the fissures may be due as much to the need of air as to the inability of the roots to pierce the clay. In a sandy subsoil the rootlets were found to ramify at will where the moisture was sufficient.

In some localities the taproot in stiff clay soil has been observed to have disappeared, probably owing to decay, and the trees, which are stunted and gnarled, are supported by the more or less superficial lateral roots; such trees are easily blown down by wind.

So far as has been observed the sal does not produce root-suckers. Shoots are sometimes produced low down on stools, some little distance below ground-level, and curving outwards appear above ground some inches away from the stool, but these can hardly be called root-suckers.

Coppicing power. As a rule the sal coppices well up to a moderate size. Shoots are rarely produced from the top of the stool, but usually from the side of it near ground-level. Mr. McIntire[1] says that in the dampest parts of Bengal, that is in the *tarai* and the Tista valley, sal is a bad coppicer. In coppice experiments near Dehra Dun in 1908–9, the best shoots were produced by stools not exceeding 2 ft. in girth. In Gorakhpur nearly all the trees up to 3 ft. in girth are found to coppice well. A number of measurements made by me in that district in 1911 showed that the strongest shoots were produced by stools varying from 10 in. to 4 ft. 2 in. in girth: within these limits the vigour rather than the size of the stools appeared to determine the vigour of the shoots produced. In Bahraich experiments carried out in 1909 resulted in no shoots being produced by stools over 4 ft. 10 in. in girth. Mr. Leete[2] found that in the Charda forest of Bahraich shoots were produced in abundance only by stools under 3½ ft. in girth. Mr. Haines says that in Bengal coppice-shoots are almost universal from stools under 1 ft. in girth, not common from stools over 2 ft. in girth, and only occasional from stools 2 to 3 ft. in girth.

[1] Notes on Sal in Bengal, For. Pamph. No. 5. 1909.

[2] Ind. Forester, xxv (1899), p. 326.

On rare occasions stumps of large size are found to produce **coppice-shoots**: in 1916 in the Singhbhum forests I found a hollow stump 9 ft. in girth, cut 3 ft. high, producing a shoot from near the top.

The number of shoots produced per stool varies greatly. Measurements made by me in the Tikri forest, Gonda, in 1911, in three plots of 4 acres each in coupes one and two years old gave the following results:

1. Age 1 year, average 2·2 shoots per stool.
2. Age 2 years, ,, 1·7 ,, ,,
3. Age 2 years, ,, 1·8 ,, ,,

Measurements made the same year in Pilibhit in a coupe one year old showed an average of 4 and a maximum of 10 shoots per stool. As many as 20 shoots have been observed on a single stool: in such cases, however, superfluous shoots are killed out, and as a rule only about 1 to 3 shoots survive to an age of say twenty or thirty years.

Trees whose vitality has been seriously impaired by drought or otherwise coppice indifferently or not at all, though experiments carried out in Bahraich in 1902–3 showed that trees dead for some distance from the top in many cases coppiced well. For a few years subsequent to the abnormal drought of 1907 and 1908, in the forests of Oudh coppice reproduction failed entirely in certain coupes where the trees had been badly affected, nothing but a sea of grass resulting from the fellings (Fig. 42). Apart from drought, coppice has failed signally in some parts of the Gorakhpur forests. This is probably due, in part at least, to the unsoundness of many of the trees felled, this being no doubt attributable to past burning and maltreatment, which has resulted in stumps which are hollow or lacking in vigour. Experiments in the Central Provinces have shown that the season of cutting has a marked influence on the production of coppice-shoots: cutting should be completed before the growing season begins, that is, before the hot season, for if it is carried out in the hot season weak shoots result in a large number of cases.

Under certain conditions the height at which stools are cut has an influence on the resulting shoots. It was noticed in Oudh some years ago that in dry localities and dry seasons stools cut a few inches from ground-level produced better results than those cut flush with the ground. This was due to the fact that the stools died down for a few inches from the top in the hot season, the cortex separating from the wood: in the case of stools cut high, although the upper part of the stool dried up the lower part remained alive and produced shoots, whereas in the case of stools cut flush with the ground the part at ground-level and immediately below it dried up, reducing the surface capable of producing shoots. Experiments carried out in 1910–11 in the Siwaliks confirmed this.

Mr. A. E. Osmaston[1] has described experiments in high and low coppicing carried out in the Gorakhpur district. Three forms of coppicing were tried: (*a*) cutting flush with the ground and trimming in the form of a convex cone, (*b*) cutting 4 to 6 in. high with similar trimming, and (*c*) cutting 4 to 6 in. high without trimming. The following results were obtained: (1) as regards the proportion of stumps producing shoots, (*a*) showed results inferior to (*b*) or (*c*); (2) as regards the average height of shoots produced there was a slight but well-marked increase in height in the case of (*b*) relative to (*a*) and of (*c*) relative to (*b*); (3) as regards the number of shoots per stool, the method of coppicing had little if any effect.

---

[1] Ind. Forester, xxxvii (1911), p. 424.

Experiments were carried out in Bahraich, in which two one-acre plots side by side were coppiced in March 1909; in one of these the stools were cut flush with the ground and in the other they were cut a few inches high. In the former 86 per cent. and in the latter 95 per cent. of the stools sent up shoots.

Drought. The most severe drought which has occurred in sal tracts within the memory of man is that of 1907 and 1908, which caused extensive damage in the *tarai* and plains forests of Oudh, and considerable local damage in the *tarai* forests farther west; the forests of the outer hills were only slightly affected.

In 1913 I published the results of an investigation into the effects of this abnormal drought and the causes of the damage done by it.[1] The effect was found to vary from place to place: in some cases the trees died off wholesale over patches of considerable extent (Fig. 43), while in many cases they died off in small groups. In coppice-with-standards coupes the standards were often found to be badly affected, while the coppice escaped (Fig. 45). All the facts of the case pointed to the direct cause of the damage being due to the failure of the monsoon rains of 1907 and 1908, resulting in the lowering of the subsoil water-level and the desiccation of the soil above that level; measurements in different wells throughout the Oudh forests showed a fall in the water-level varying from 2 to 26 ft. It was noticeable that deep-rooted species suffered more than shallow-rooted species, sal suffering more than any of its companions. The reason of this appears to be that with the lowering of the water-level the strata for some distance above it, from which the roots of the deep-rooted species drew their supplies of water, became too dry to afford the requisite supply of moisture; on the other hand the surface feeders obtained sufficient moisture from the scanty rainfall which fell in the years of drought and moistened the surface layers.

Cases of wholesale dying off of trees over large patches were found, by means of a series of well-borings made across these areas and adjacent unaffected areas, to be due to the presence of thick deposits of pure sand for some distance above the normal water-level. When the water-level sank these deposits of sand were unable to retain a sufficiency of water to keep the trees alive; in the adjoining unaffected areas, on the other hand, the subsoil contained no thick layers of sand, but consisted of varying proportions of sand and clay constituting a subsoil more retentive of moisture. The thick deposits of pure sand in these alluvial tracts may be taken to represent former sand-banks produced by river action, and now buried several feet below the surface owing to the superimposition of more clayey beds; this would explain the fact that in many cases the badly-affected areas, denoting the presence of these sand-banks, were long and narrow in shape and were observed to follow regular lines of varying breadth.

---

[1] For. Bull. No. 22.

A study of the causes of the damage done by and the effects of the abnormal drought in question, which in some localities led to the entire suspension of working plans operations, with the object of removing dead trees, indicated the hopelessness of devising measures for counteracting its effects to any great extent. The following measures may serve to mitigate the extent of damage caused by a similar catastrophe in future:

1. High forest would appear to be more suitable than coppice-with-standards in localities subject to drought, in view of the susceptibility of standards to injury.

2. The retention of a suitable mixture of drought-hardy trees in sal forests is desirable. Among those found to be particularly hardy during the abnormal drought in the Oudh forests were *Ficus* spp., *Diospyros tomentosa*, *Stereospermum suaveolens*, and *Miliusa velutina*; slightly less hardy, but still decidedly hardy, were *Gardenia turgida*, *Holarrhena antidysenterica*, *Ougeinia dalbergioides*, *Cassia Fistula*. *Cordia Myxa*, *Bauhinia racemosa*, *Casearia tomentosa*, *Butea frondosa*, *Bridelia retusa*, *Odina Wodier*, *Eugenia Jambolana*, *Ehretia laevis*, *Mallotus philippinensis*, *Carissa spinarum*, *Lagerstroemia parviflora*, *Careya arborea*, *Grewia* spp., *Kydia calycina*, *Randia uliginosa*, *R. dumetorum*, *Zizyphus Xylopyrus*, and *Aegle Marmelos*.

3. An undergrowth of drought-hardy species is of special importance: even though the presence of a heavy undergrowth was not proved to be a preventive of damage by drought, the value of an undergrowth of hardy species as a soil-covering, in the event of the destruction of the overwood by drought, would be considerable.

Frost. Sal withstands frost better than many of its associates, but from the fact that it often occurs in grassy tracts and other localities subject to severe frost, it is particularly exposed to injury, and suffers accordingly. The commonest forms of injury are the killing back of seedlings and coppice-shoots, often for many years in succession, until they are at last able to shoot up, and injury to the crowns of poles and saplings, the leading shoots being killed and numerous epicormic branches being produced up the stems. Trees affected in this way have a characteristic appearance not unlike that of a Lombardy poplar (Fig. 46).

The abnormal frost in the early part of 1905 did enormous damage in the sal forests of northern India, particularly on low-lying ground. Saplings and small poles were killed down to ground-level, while large poles and even trees of considerable height had their tops killed for 10 to 20 ft. or more. Observations made some years later in the Dehra Dun forests showed that the loss of increment alone amounted on an average to at least ten years' growth. More serious, however, was the fact that rot had in most cases spread down the interior of the stem, starting from the base of the dead top. One or more new leaders had been produced from the living tissue at this point, the result being a bayonet-shaped or forked stem. For years after the occurrence of the abnormal frost the new leaders so produced frequently broke off, owing to wind, at the tender callus at their base. Trees damaged in the manner described can never be expected to produce clean sound boles, and one lesson learned from this abnormal frost is that it would be more profitable to cut back as many badly damaged poles and saplings, as circumstances will permit, for

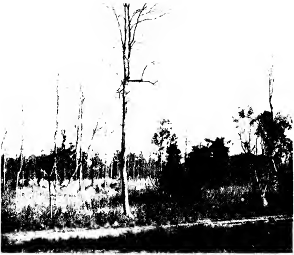

Fig. 43.—*Shorea robusta* forest killed by severe drought of 1907 and 1908, South Kheri, United Provinces.

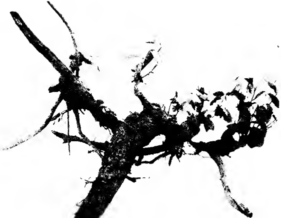

Fig. 44.—*Shorea robusta* root-stock produced on *chandar* land, Pilibhit, United Provinces; hollow decaying taproot cut through (bottom of picture), several lateral roots cut through, and several groups of shoots from gnarled remnants of stumps.

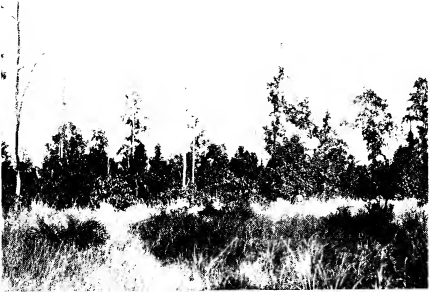

FIG. 45. *Shorea robusta* standards killed in coppice-with-standards by the abnormal drought of 1907 and 1908. Gonda, United Provinces.

a few years after the occurrence of such a frost, thus allowing of new healthy coppice growth taking their place.

In the Dehra Dun forests it was noticeable during the abnormal frost of 1905 that overhead shade which was sufficient to suppress young sal growth was not sufficient to prevent damage to it by frost. A similar observation has been recorded by Mr. C. M. McCrie[1] in the case of an abnormal frost in February 1916 in the Balaghat district, Central Provinces; in a *Pinus longifolia* plantation near Supkhar sal shoots which were so thoroughly shaded by the pine as to be on the verge of suppression had been more or less cut back to ground-level by frost. These observations are of great importance in showing that in a really severe frost overhead cover cannot be relied on to afford protection. On the other hand the value of side protection has been demonstrated in the experiments referred to above under 'the seedling'.

The value of air circulation as a preventive of frost damage is often seen in grassy tracts, where sal establishes itself more readily along the edges of cleared lines, and in similar places where there is free air circulation, than in the grass-covered portions of the area. The value of side protection in such areas is also seen from the fact that sal tends to establish itself preferably beside clumps of trees or along the edge of the forest. Frost damage becomes accentuated in dry years, and hence in years of abnormal drought frost damage may occur in localities ordinarily free from it.

One of the most remarkable effects of frost is seen in the grassy blanks in the Pilibhit and South Kheri forests of the United Provinces, and known locally as *chandar* lands. These blanks are thickly covered with a shrubby growth of sal, the shoots springing up annually from a thickened root-stock and being killed back every year by frost (see Figs. 21 and 22). These *chandar* lands vary in extent from a few acres to some hundreds of acres. They are situated on the alluvial plains, some of them occupying slight depressions, while others are not appreciably lower than the surrounding forests. The soil is often, but not invariably, pure micaceous sand. Some of the *chandar* lands are fire-protected and some are burnt annually. As far as appearances go fire-protection seems to have no appreciable effect on the establishment of sal reproduction; it results in a very rank growth of grass, chiefly *Anthistiria gigantea*, but does not appear to assist the sal in any marked degree. In mild seasons some of the sal shoots escape damage by frost here and there, singly or in groups, and after a succession of mild seasons may even establish themselves permanently. The most favourable positions for the establishment of the sal are along the edges of roads and fire-lines, where owing to the free air circulation established saplings often form a regular fringe, or along the edges of the forest and in the immediate neighbourhood of clumps of trees, where side protection is obtained. The sal shoots which spring up annually on *chandar* lands are found in clumps like coppice-shoots; they are comparatively thin, and as a rule reach a height of 3 or 4 ft. They spring from an enlarged woody root-stock, there being one or more clumps to each root-stock, according to the size and vitality of the latter. In comparatively young root-stocks only one clump of shoots is sometimes seen, and a regular taproot is found; the latter, however, generally rots away as the stump increases in age, and is replaced by long lateral roots spreading not far below the surface of the ground. In many cases the original stool has entirely decayed, leaving a straggling gnarled or twisted growth, which tends to branch in different directions, each branch sending out a clump of shoots (see Fig. 44). In such a case the clumps of shoots often appear to form a ring which gradually enlarges until it is several feet in diameter; this ring represents the original outer growing portions of the stump which have spread centrifugally with advancing age. Sometimes portions of this ring detach themselves from the original stump owing to the decay of the latter, and form independent root-stocks.

---

[1] Annual Forest Report, 1915-16.

The origin of *chandar* lands is not known with certainty. It has been suggested that they represent former swamps, but this seems unlikely owing to the fact that the soil is often pure sand, that they do not necessarily occupy depressions, and that sal does not grow in swamps and never could have originated in them. It is possible that they may be areas formerly cleared of tree-growth by man. In this case the stumps were probably subjected to ill treatment, by burning or otherwise, sufficiently severe to impair their vitality: this conjecture follows from the fact that trees recently felled, and not fire-protected, have been seen to reproduce themselves at once by vigorous coppice-shoots in areas adjoining or situated within existing *chandar* lands, the annual frosts being insufficient to kill back the coppice-shoots which sprang from the felled trees. Another possible theory is that the vitality of the stools may have become impaired by some abnormal climatic phenomenon such as excessive drought; an examination of the subsoil of *chandar* lands as compared with adjoining forest land might throw some light on the subject.

Attempts have been made to restock *chandar* lands, but so far experiments carried out with the view of effecting the establishment of existing sal shoots have not proved successful. These experiments have consisted of sheltering sal with grass cowls, clearing narrow strips to produce air circulation, producing a pall of smoke and water vapour, excavating parallel drains, and introducing frost-hardy nurses. It is probable that the difficulty will eventually be solved by restocking *chandar* lands with frost-hardy species when the most suitable species and the best methods of cultivating and protecting them have been ascertained: so far damage by pigs and porcupines has been the most serious danger to be contended with in this respect. If irrigation could be introduced, this might help matters by producing more moisture in the air and thus lessening the damage from frost.

Fire. Sal is one of the most fire-resistant of all the species of its region: this is clear from the manner in which it establishes itself in burnt savannahs where the majority of species are unable to survive. The process of establishment is no doubt slow, since the sal is burnt back year after year, but its power of recovery from the base is remarkable. Former damage from fire is undoubtedly the cause of much unsoundness and hollowness in sal trees at the present day, particularly in forests of the drier types. The sal trees in the Bengal Duars, however, have been observed to be remarkably sound, even at the base, and this in spite of the fact that the majority, if not all of them, must have originated in burnt savannah lands. In the dry and semi-moist types of sal forest the advantages of fire-protection are everywhere most marked; this is particularly the case for some years after fire-protection has been introduced in forests hitherto subjected to burning, and young growth previously burnt back annually is able to start upward growth. In the moist types of sal forest occurring in Bengal and Assam the effects of continued fire-protection on the natural reproduction of the sal, in causing the growth of a dense evergreen undergrowth and in introducing unfavourable soil factors, are most adverse, as has been explained above.

Damage by fire is much aggravated after the occurrence of severe drought, such as that which affected the forests of Oudh in 1907 and 1908. The trees which are killed or partly killed by drought, and have strips of dead bark clinging to them, may be wholly consumed by fire, which runs up the dead bark and causes crown fires of great intensity. Moreover, the lightening of the canopy owing to the death of a certain proportion of the trees induces a rank growth of grass which still further aggravates the risk of fire and the damage caused by it.

Storms. Owing to its strong deep root-system the sal is not ordinarily liable to be thrown by wind, but on badly-drained clayey ground the taproot sometimes rots, and the trees are readily blown down. By far the greatest damage by storms and hail is occasioned by the destruction of the flowers and immature fruits from February or March to June. Hailstorms occasionally do damage by stripping off the young leaves and twigs.

Animal damage. Injury by animals occurs in the younger stages. Seedlings, as already mentioned, suffer much from damage by pigs and porcupines, which uproot the young plants. Wild elephants sometimes strip the bark off the lower parts of poles and smaller-sized trees. Browsing by deer and cattle is responsible for a great deal of damage, particularly in coppice coupes. Heavy grazing may be responsible for a complete absence of natural reproduction, partly owing to browsing and partly owing to the hardening of the soil. As the sal plants put out their fresh foliage early in the hot season when the grass is dry and unpalatable, they are particularly susceptible to the attacks of browsing animals: this is more especially the case in fire-protected tracts, where fresh green grass does not spring up early in the hot season, as it does in burnt areas. The sal has numerous insect enemies, but it is beyond the scope of this work to describe them. The barking of logs as soon after felling as possible is recognized as a necessary precaution to prevent the ingress of wood-boring beetles which lay their eggs in the bark of fallen trees.

Parasitic plants. In some localities, for instance in parts of Bihar and Orissa, sal suffers much from the attacks of *Loranthus*; in such cases affected trees should be cut out as far as possible in thinnings.

A virulent fungoid pest of the sal has recently come to light in the shape of *Polyporus Shoreae*, Wakefield, the sal root fungus.[1] This fungus was first detected in 1914 by Mr. C. F. Beeson in the Bengal Duars, where it must be held accountable for numerous mysterious cases of death among sal trees in that tract which had been noticed for several years previously. It has since been reported to a greater or less extent in other parts of Bengal and in parts of Assam, Bihar and Orissa, the United Provinces, and the Central Provinces. It appears to be commoner in moist than in dry types of forest. The outward sign of the fungus attack is the death of sal trees, usually two or three together or in larger groups. At the base of an affected stem may be found groups of dark brown bracket-like sporophores, often 15 in. or more in diameter; these are soon consumed by white ants, so that in many cases they are not traceable. If the roots of the tree be cut open they will be found to be permeated by the whitish mycelium, which usually appears in the form of numerous flecks or pockets. The mycelium attacks roots of all sizes, sometimes completely destroying the taproot, and spreads into the base of the bole. The freshly attacked tissues of the cortex have a characteristic odour of decaying resin, and are wet and sticky. This fungus is at present under study with the view of devising methods of combating its ravages.

---

[1] Kew Bull., No. 3, 1916, p. 72.

Mr. Haines[1] records from Orissa another fungus, not yet identified, which he terms the sal thicket fungus. 'This form, or species,' he says, 'is not apparently a root fungus, but the mycelium appears on the young stems and branches and spreads on to the leaves. In older parts it assumes the form of thicker white strands and bands. It often appears to originate near a wound caused by the breaking of a branch, the leaves turn brown and die, branches die off and break away at the stem or the whole top dies and breaks off. Ultimately, after many attempts at putting out new shoots, which causes a characteristic nodose appearance of the stem, the whole plant may die. This dying back and breaking off of the branches may be the cause of the fungus appearing to originate at wounds. Now, the great point about this fungus . . . is that it always appears in overcrowded thickets, or on saplings under the shade of bamboos, or in other places where light is apparently insufficient; and it may, therefore, I think, be rightly classified among those bad conditions producing unsoundness which can be removed by future treatment. Improvement fellings, thinnings, and cleanings seem to be the remedy, and in grave cases, almost certainly, fire and coppice.'

Mr. Haines has also found on sal trees in the Palamau district, Bihar and Orissa, a fungus closely resembling *Xylaria polymorpha*, which is parasitic on the oak in Europe; it was found on a number of dead sal trees and on a half-green tree.

NATURAL REPRODUCTION. The natural reproduction of the sal presents many features which have always been a puzzle even to those who have studied the question for years. In some localities reproduction springs up in such profusion and with such vigour that nothing can stop it; in others, where, as far as the eye can judge, conditions appear to be similar, reproduction is completely absent for no apparent reason. The problem of the natural reproduction of sal, as of other species, can best be approached by considering separately the various factors affecting it. If these are understood it may be possible in individual cases to assign reasons for good or bad reproduction and to suggest remedies for the latter. Some examples will also be quoted with the view of illustrating certain points of interest connected with the subject: some of the examples show that a combination of circumstances specially favourable to natural reproduction is in some localities of rather rare occurrence. The various factors which bear on natural reproduction may be conveniently considered under three heads: (1) seeding, (2) germination, (3) establishment of the seedling.

---

[1] Ind. Forester, xliii (1917), p. 311.

1. *Seeding.* Information on seed-bearers and seeding has been given under 'flowering and fruiting'. A seed-crop of good promise may be wholly or partially destroyed by storms or hail between the time of flowering and the time of ripening of the fruit. A report from the Santal Parganas states that 80 per cent. of the fruit-crop is blown down in the hot season before the fruit ripens, and that of the remaining 20 per cent. only a very small proportion germinates.[1] In this case the lack of reproduction may be put down mainly to unfavourable seeding conditions. The seed-crop is sometimes much damaged by insects, while in some localities considerable quantities of seed are destroyed by porcupines after falling. As regards the distance to which seed is ordinarily carried by breezes at the time of ripening, in 1910, following on a very favourable seed-year, seedlings were noticed in grassy blanks in the Dehra Dun forests well over 100 yds. from the nearest seed-bearer. This distance perhaps represents the limit to which seedlings spring up in any abundance on blank areas under ordinary conditions, though fruits are no doubt carried very much farther by high winds.

2. *Germination.* The most important factor affecting the germination of the seed is the occurrence of the monsoon rains. The seed falls at or immediately before the commencement of the rains, and if they are delayed many days after the fall of the seed, germination fails. In this way an abundant seed-year may fail partially or entirely to effect any natural reproduction; the combination of a good seed-year and timely commencement of the monsoon, resulting in abundant reproduction, is not of such common occurrence as might be supposed.

Experiments at Dehra Dun have shown that even with favourable rainfall conditions a certain proportion of the seed perishes during germination on bare hard ground exposed all day to the sun, through the radicle being dried up before it can penetrate the soil; where there is protection by grass there is less mortality from this cause. In very damp places, again, the radicle sometimes rots during germination, death resulting. The radicle is also subject to insect attacks. The effect of a thick layer of dead sal leaves on the germination of the seed is most marked; an experiment which I carried out at Dehra Dun in 1914 gave the following results:[2]

In the open, exposed to the sun, sal seed falling on a layer of dead leaves fails to germinate, or if it does germinate it perishes rapidly: under shade, with complete protection from the sun, the seed germinates satisfactorily. In the latter case, however, as will be seen below, the seedlings fail to survive after the end of the rainy season. Side by side with the leaf-covered plots were bare plots with the soil completely exposed, on which sal seed was also scattered. On these bare plots germination was quite satisfactory both in the shade and in the open. Applying these results to forest conditions, although there will usually be patches of bare ground varying in extent on which germination is successful, on the other hand there will generally be patches, either under shade or in gaps exposed to the sun, where the dead leaves have accumulated sufficiently to cause a certain proportion of failure. The most practical remedy would be the burning of the layer of leaves when a good seed-year is in prospect.

---

[1] Ind. Forester, xxvi (1900), p. 389.

[2] *Ibid.*, xlii (1916), p. 57.

Observations made in the Dehra Dun forests in 1910, a very favourable seed-year, showed that germination takes place successfully under the densest forest shade. Mr. Hole[1] has, however, demonstrated that in these forests the percentage of germination in the shade of the forest is lower than it is in the open with full overhead light, but with light side shade.

The aptitude of sal seed for germinating on very porous soil is sometimes exemplified in exaggerated form, as in a case noticed in December 1910 at the side of a road running through sal forest near Dehra Dun, where numbers of vigorous sal seedlings were found growing on a heap of road-metal about 1 ft. high; they had sent their taproots down through the loose metal into the earth beneath and had firmly established them there.

3. *Establishment of the seedling.* (a) *Dying back.* The main factors affecting the establishment of natural reproduction are those concerned with the death or dying back of seedlings. These have already been dealt with in detailing the results of Mr. Hole's experiments, under 'the seedling'. To recapitulate briefly, these experiments showed that the chief causes of mortality are: first, an injurious soil factor which is operative during the rainy season, and which may be termed bad soil-aeration; and second, drought, which acts during the season of short rainfall from September to June. The former is present chiefly in non-porous soils with a small water-free air space and a high percentage of water and organic matter. The latter is the direct consequence of the former, since in a badly-aerated soil the root-system is insufficiently developed to be able to withstand the effects of the dry season. As regards measures necessary for securing reproduction, Mr. Hole classifies sal forests into moist and dry types, in which bad soil-aeration and drought respectively are the dominant factors, and advocates the following treatment in either case. In moist forests: clear-felling in strips or patches, removal of dead leaves (if necessary by burning), working up the soil, sowing sal seed, and weeding during the first rains; this secures ideal conditions for the development of sal seedlings, these conditions being a well-aerated seed-bed free from raw humus, full overhead light, and light protective side shade. Where these measures are impracticable the alternative proposed is to remove dead leaves by light leaf fires or otherwise, thereby increasing the proportion of seedlings, and then to remove the overhead cover early. In dry forests two methods are suggested: (i) introducing an underwood as a soil-protection, thus in time converting the forest into one of the moist type, which could then be treated as such; (ii) preventing the run-off of rain-water and encouraging its percolation into the soil by surface cultivation, trenching, or small embankments, this being accompanied if necessary by mulching in the dry season.

(b) *Effect of dead leaves.* An experiment dealing with the mechanical effect of a layer of dead leaves on the germination of the sal seed has already been alluded to; the effect of such a leaf layer on the survival of the resulting seedlings has been brought out by the same experiment. It was found that seedlings which germinated on a layer of dead leaves under shade developed satisfactorily above ground during the first rains, but the taproots, instead of descending into the mineral soil, spread laterally between the layers of wet leaves, deriving sustenance from the moist earthy matter there, and sending

---

[1] Ind. Forester, xlii (1916), p. 59.

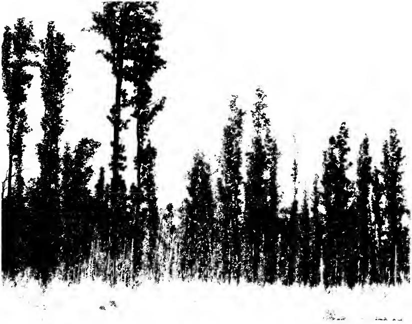

FIG. 46. *Shorea robusta*, effect of damage by frost, Lansdowne division, United Provinces.

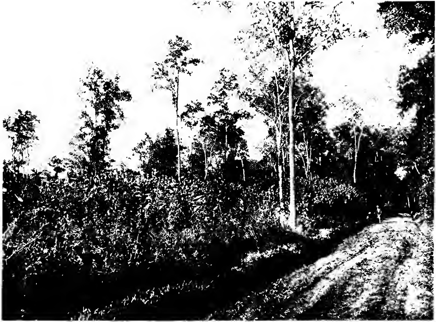

Fig. 17.—*Shorea robusta*, moist forest opened out and burnt with the view of inducing a growth of grass and effecting natural reproduction of sal, but actually resulting in a dense growth of *Macaranga* and *Alpinia*, Buxa division, Bengal.

out long fine lateral rootlets. There was no sign of rotting of the roots as in badly-aerated soil, but the roots had no foothold, and the seedlings could easily be pulled up with all the roots intact. In consequence nearly all the seedlings died off when the layer of leaves dried up after the end of the rainy season, many falling over for want of support; some survived for a few months where the leaf layer was scanty, but these eventually succumbed. In the case of seed sown on bare ground in adjacent plots, both under shade and in the open, the seedlings produced long taproots which obtained a firm hold in the mineral soil. It is thus evident that the removal of the layer of dead leaves on the ground, by fire or otherwise, is an aid to reproduction in counteracting the mechanical effect alone of the leaf layer.

(c) *Light.* The effect of light, as such, on the establishment of natural reproduction requires further investigation. It is a matter of common observation everywhere that the admission of full overhead light is necessary for the best development of a young sal crop. Mr. Hole's experiments have shown that in the open with full overhead light, but with light side shade, the percentage of seedlings which germinate and survive is decidedly higher, and the percentage which die back is decidedly lower, than in the shade of the forest; he ascertained, however, that the inferior results in the forest shade were due primarily to an injurious soil factor connected with the decomposition of humus and not to deficient light. Thus in the case of young seedlings, although want of light in itself may possibly not become an adverse factor until a certain degree of shade is reached, its correlation with factors which are adverse even under slight overhead shade is of importance. The protective value of side shade, as opposed to overhead shade, has already been referred to.

As a general rule, other conditions being favourable, the admission of light sufficient to cause the appearance of grass in moderate quantity will induce the appearance of sal reproduction, the establishment of which depends on a drastic opening out of the canopy. An exception, however, should be noted in the case of the very moist types of forest occurring in the Duars of Bengal and Assam and in certain other localities. Here the admission of light results in a rank growth of weeds and climbers which effectually prevents the establishment of sal reproduction, even in places where the undergrowth is cut and burnt to induce a growth of grass (see Figs. 47 and 48).

(d) *Frost,* as a factor adverse to natural reproduction, is of importance in open places, chiefly in grassy savannahs and blanks within the forest where seedlings may be killed back year after year. Under the cover of a canopy frost does not as a rule affect young plants except in abnormal years, as in the spring of 1905, when extensive damage was done even under fairly dense overhead cover. In grassy savannahs seedlings often remain undamaged as long as they are sheltered by the grass, but as soon as they appear above the level of the grass they are cut back by frost year after year. In such places reproduction establishes itself best along the edge of the forest, where it obtains side protection, or under and around isolated trees or clumps of trees; one of the most important protective trees in the savannah tracts of northern India is *Eugenia operculata*. Along the sides of roads or cleared lines running through frosty savannahs natural reproduction tends to establish itself more readily than on the grass-covered ground owing to the freer circulation of air.

The value of side shade as a protection against frost and drought is well recognized in European forestry, and Wagner[1] has shown that in the case of the spruce lateral protection from the south-east gives the greatest immunity from damage by these agencies. The value of side protection has been similarly corroborated by Mr. Hole in the course of experiments alluded to above. He found that in localities subject to frost in the Dehra Dun forests, whereas light side shade on the south is not sufficient to protect sal seedlings from frost on the edge of an open grass-land surrounded by forest, seedlings springing up on a continuous cleared strip 100 ft. wide running ENE. to WSW. suffered no damage. He also found that in an area subject to severe frost the plan of clear-felling a gap 60 ft. wide, hoeing up the ground, sowing sal seed, and weeding during the first rains not only secured practically ideal development but prevented any frost damage.

(e) *Grazing.* Damage done by browsing is worst in the hot season when the fresh young sal leaves appear, as they are preferred to the dry withered grass. In burnt grassy areas the new green grass which springs up is preferred to the sal shoots, and the latter are less exposed to damage by grazing. Where heavy grazing is admitted the natural reproduction of sal may be entirely prevented, while the exclusion of grazing may result in plentiful reproduction where none existed before. Absence of reproduction in grazed areas may be due as much to the hardening of the soil by the tread of the cattle as to actual browsing. This hardening of the soil is particularly noticeable round the edges of the forests, where cattle are apt to congregate to escape the heat of the sun outside, or, in plains forests, on slightly rising ground, where they collect during the rainy season to escape the floods.

(f) *Hardened soil and bad drainage.* Natural reproduction frequently fails to establish itself on soil which has become hardened by grazing or otherwise, or is stiff through an excess of clay, or where the drainage is bad. Such conditions are common in some of the plains forests, as in parts of the Gorakhpur district, United Provinces. Here experiments have shown that a heavy opening of the canopy, thorough digging of the soil, and the exclusion of grazing are sufficient to ensure good reproduction on the worst and stiffest soils. In the Kalianpur block of the Haldwani forest division, United Provinces, in an area which had been heavily grazed for years and in which the soil had become excessively hard and barren, a plot was fenced off in May 1913, and within it the soil was dug up. In November the whole plot was found to be covered with seedlings, while the surrounding ground was quite bare. These examples serve to indicate the quick response to thorough aeration of the soil under the most unfavourable conditions.

(g) *Fire and fire-protection.* Observations everywhere show that in the dry and moderately moist types of forest found throughout the greater part of the north-western and peninsular sal regions the results of fire-protection on the establishment of natural reproduction are wholly beneficial, and that fire is one of the most serious obstacles to its successful establishment. Prior to the fall of the seed, however, fire is useful in removing the layer of dead

---

[1] C. Wagner, Die Grundlagen der räumlichen Ordnung im Walde.

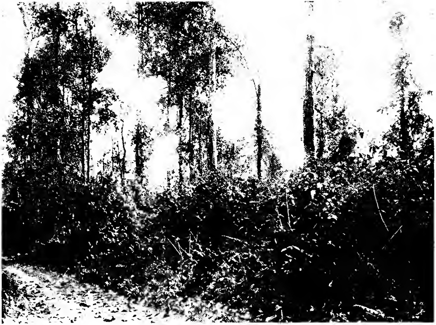

FIG. 48.—*Shorea robusta*: experimental seeding felling in moist forest, the overwood being opened out and undergrowth cut and burnt, resulting not in sal reproduction but in a dense mass of weeds and climbers. Goalpara, Assam.

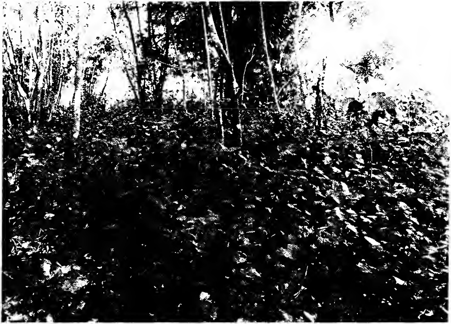

Fig. 49. *Shorea robusta*, dense mass of natural reproduction up to 2 ft. high under *Macaranga denticulata* on an abandoned fire-line, South Muraghat forest, Jalpaiguri, Bengal.

leaves and thus increasing the number of seedlings which germinate and survive. In grassy tracts, also, where continued fire-protection in the case of certain species of grass produces a dense matted growth, fire before the fall of the seed is beneficial in enabling it to reach the ground and to find a good germinating bed.

In the very moist sal forests found in the Bengal Duars and in Assam, however, continued fire-protection has so altered the type of forest that natural reproduction cannot now establish itself. The Duars forests have been described above (pp. 70–73). It has been explained that these forests originally sprung up in burnt savannah lands, the process being still in operation where fire-protection has not yet been introduced. The process of establishment of reproduction is doubtless a slow one, as the fires in these grassy tracts are of great severity, but the sal after repeated burning back eventually establishes itself; the process is illustrated in Figs. 31, 32, and 33. The introduction of fire-protection must for a time have effected the establishment of large numbers of seedlings and saplings, but here its benefit ended, for with continued fire-protection a dense and largely evergreen undergrowth takes possession of the ground, while in many places a luxuriant growth of climbers forms an impenetrable mass: the nature of the undergrowth is illustrated in Figs. 34, 35, and 36. Much sal seed fails to reach the ground through this dense matted undergrowth, but a considerable quantity reaches the ground and germinates, the seedlings persisting sometimes for a few years. Throughout these moist forests, however, for all practical purposes no established sal reproduction is to be found where fire-protection has been in operation for any length of time. It was hoped at one time that repeated cleanings would effect the establishment of existing seedlings, and these operations were carried out in some cases for five consecutive years, abundant light being admitted. This, however, had no effect, the seedlings showing no progress, although seedlings grown in ploughed land outside the forest in this region show remarkably rapid growth and do not ordinarily die back. Even on an experimental cleared line through the forest natural seedlings failed to establish themselves. This pointed to the adverse factor being not want of light but an injurious soil-factor, presumably connected with bad soil-aeration brought about by an excess of moisture and organic matter in the soil, the result of the altered conditions produced by continued fire-protection. Attempts to establish natural reproduction by the admission of light, which only intensifies the dense undergrowth, and by intensive cleanings, having failed, other measures, the object of which is completely to alter the soil conditions, have had to be devised. In the moister types attempts to burn the undergrowth are of no avail, since it will not burn satisfactorily. Cutting and burning it has proved little better: in many places it only results in a dense regrowth of weeds and climbers, while even where there is a tendency towards the replacement of the dense undergrowth by savannah grasses the process is slow and costly. It has therefore been decided to regenerate by means of clear-felling, cultivating for two years or more with field crops, and sowing up artificially with sal. So far this treatment is only in the experimental stage, but it gives good promise of success. It is, however, limited by the number of cultivators available, and hence for the present it is being confined

28397.

to the moister types of forest; in the drier types where **sau grass** (***Pollinia ciliata***) is the chief soil-covering and burning is to a large extent possible, the grass is fired annually in the hope of eliminating it and causing the appearance of savannah grasses, in which sal reproduction will have a better chance of establishing itself.

(h) *Indicator plants and nurses.* Apart from grasses and the nurses already mentioned, there are certain other plants which indicate soil conditions suitable for the reproduction of sal or which assist in its establishment. One of the most characteristic of these is ***Flemingia Chappar***, a gregarious leguminous undershrub reaching a height of about 3 to 6 ft. It is indicative of fairly moist fresh soil, often with a clayey tendency: its cover is light, and the ground beneath it is often bare. Under it sal seedlings are often found in quantity, and they appear to have no difficulty in making their way through it: where it occurs it is an almost certain sign of the presence of sal reproduction where there are seed-bearers in the vicinity. The same applies to *Indigofera arborea*, a leguminous shrub 4-8 ft. high, which is very common in the sal forests of Singhbhum and other parts of Chota Nagpur. ***Clerodendron infortunatum*** is an undershrub forming dense masses, usually in rich soil under shade: it is immune from damage by grazing, and kills out grass. Where it is dense sal seedlings are unable to survive under its shade: after occupying the ground for some time, however, it thins itself out, and as it is a good soil-improver and provides a good germinating bed, sal seedlings are often found in great abundance under it when it has reached the stage of opening itself out. *Woodfordia floribunda* acts as a useful nurse to sal on abandoned clearings, particularly in dry localities. On these clearings it soon takes possession of the ground. It resists frost and grazing, and under its light shade sal reproduction appears and is protected from drought, frost, and cattle. The sal makes its way through the *Woodfordia* and eventually kills it out. Thus sal pole crops which have sprung up on abandoned cultivation often have remnants of an undergrowth of *Woodfordia* which is gradually dying out.

The presence of numerous sal seedlings under other plants, however, is by no means always a sign that these plants are favourable to the establishment of sal reproduction. One of the most striking examples of this is seen in the case of *Macaranga denticulata*, a moderate-sized fast-growing euphorbiaceous tree common throughout the moist parts of the Bengal Duars. It has remarkable power of invading savannah tracts when fire-protection is introduced, and killing out the grass. For a time the ground may remain bare under it, but eventually ferns and an evergreen undergrowth make their appearance, while shade-bearing evergreen tree species establish themselves under its shade and in time supplant it. In the earlier stages of the existence of a crop of *Macaranga*, before the evergreen undergrowth takes possession of the ground, sal seedlings are sometimes found in quantity and may persist for several years in places where the drainage is good. Fig. 49 gives some idea of the profusion with which sal seedlings may sometimes occur under it. Such instances, which are exceptional, are to be found in a few places where the drainage is particularly good. Yet they have led to the belief that *Macaranga* is an excellent nurse for the sal. It should be noted that in the Duars sal seedlings growing in the open under favourable conditions do not die back, but shoot straight up from the seed and become established saplings in a few years. The reproduction, both of sal and of *Macaranga*, shown in **Fig. 49,** sprang up on a fire-line abandoned eight years previously, and if the sal had not remained under the faster growing *Macaranga* it should have reached a height of nearly 30 ft. Instead of this, owing to the unfavourable conditions produced by the *Macaranga* it actually consisted of numbers of thin whippy shoots up to 2 ft. high which had died back repeatedly and which sprang from thickened root-stocks evidently dating from the time when the fire-line was annually cleared and burnt. The sal in this instance was undoubtedly older than the *Macaranga* suppressing it. In all other similar instances examined the suppressed sal was found to be as old as or older than the *Macaranga*. In one case sal and *Macaranga* were sown together eight years previously: the *Macaranga* had reached a height of 30 to 35 ft., while the few sal plants which survived had thin whippy shoots not more than 3 to 4 ft. high. A careful search throughout the Duars did not reveal a single vigorous established sal sapling under the cover of *Macaranga*. Thus under natural conditions in the Duars it cannot be said that *Macaranga* is of any benefit to sal reproduction, but decidedly the reverse. It is quite possible, however, that owing to its wonderful power of killing out rank savannah grasses it may yet be put to a useful purpose as a stage in the establishment of sal reproduction; if so it will be necessary to cut it out at the earliest possible opportunity, otherwise the sal will fail to establish itself.

Bamboos, provided their cover is open, are not inimical to the establishment of sal reproduction, but dense bamboo cover is harmful. Experimental sowings under the somewhat dense shade of a plantation of *Bambusa burmanica* near Dehra Dun resulted in failure, even where the soil was well aerated by hoeing up. The seedlings survived the rainy season without dying back, but gradually died off subsequently. The adverse factor here was apparently want of light, since a few seedlings towards the edge of the plantation survived. In flowered bamboo areas, both of *Dendrocalamus strictus* and *Bambusa arundinacea*, the dense young bamboo growth quickly suppresses any sal seedlings. Once the young bamboo growth has had a start little can be done to keep it in check without undue expenditure. Experiments in Burma have shown that the most effective method of keeping bamboo reproduction in check is to deal with the clumps during the year of seeding. The flowered area is fire-protected until the seed has ripened and fallen, and then burning is carried out late in the hot season; even thus only a portion of the seed is destroyed, and burning has to be repeated in subsequent years.

The natural reproduction of sal in grassy savannahs has already been alluded to, and it has been noted that of all the grasses in sal tracts *Saccharum Narenga* is the one most favourable to the establishment of natural reproduction. Sal seedlings are sometimes found in abundance under *Anthistiria gigantea*; although this grass has a somewhat dense cover there is usually an expanse of clean bare soil between the clumps, on which the seedlings are able to thrive. It has often been observed that in favourable seed-years seedlings spring up in greater quantity after a fire than on unburnt savannah land, where the dense growth of grass probably prevents much of the seed from reaching the ground; the burning of grass-lands near seed-bearers in a good seed-year is therefore a useful measure. A characteristic feature of grass-lands adjacent to sal forest is the manner in which natural reproduction of sal appears round the edge of the forest and tends to spread gradually into the grass-land. In the savannahs of northern India sal reproduction is often preceded and aided by natural nurses which kill out the grass, reducing the danger from fire and serving to protect the young sal from frost. Of these some of the most important are ***Mallotus philippinensis*, *Eugenia operculata*, *Lagerstroemia parviflora*, *Holarrhena antidysenterica***, and ***Miliusa velutina***. In many savannah tracts frost is one of the greatest hindrances to the establishment of natural reproduction, particularly where air circulation is deficient.

(i) *Seasonal variations.* Apart from the all-important factor of the timely commencement of the monsoon rains at the time the seed falls, there are other climatic factors which influence the establishment of natural reproduction. These factors, which apparently depend on seasonal variations, no doubt act differently in different localities and types of forest. They have as yet been insufficiently studied, but such instances as have come to notice, in which they have operated, indicate that they may be of great importance, so much so that other conditions being equal they may be the deciding factor in regenerating in one year considerable tracts of forest where natural reproduction has been a failure for many years. Two instances of this may be quoted from the United Provinces, one affecting the sub-Himalayan forests and the other the plains forests of Gorakhpur.

Over a considerable part of the sub-Himalayan tract the year 1913 was one of the most successful seed-years within the memory of man. I visited some of the sal forests of this tract in February 1914 and found the most prolific reproduction, even in tracts where there had been little or no reproduction within the past thirty or forty years. In the Lakhmanmandi forest, consisting of more or less even-aged sal forest approaching maturity, but in which little or no reproduction had hitherto appeared, the ground over the whole block, some 400 acres in extent, was thickly carpeted with sal seedlings, which were so thick in parts as to hide the ground completely. Similar prolific reproduction was noticeable in the adjoining Sunmanthapla block. An old inhabitant of the Mundal valley remembered similar prolific reproduction about forty years previously. Some open fields were abandoned about that time, and became covered with a plentiful crop of sal seedlings. The site of these fields is now marked by a dense even-aged sal pole crop. Now the seeding and climatic conditions of the year 1913 were somewhat abnormal. A prolific seeding of the sal was accompanied by an abnormally early break of the rains about the middle of May instead of the end of June or beginning of July. This early commencement was followed by an abnormally early cessation of the rains, in the first half of August. The survival of vast quantities of vigorous seedlings up to the following February indicated that climatic conditions were specially favourable. The abnormally early break of the rains was certainly a favourable factor in ensuring successful germination; it is possible, but not certain, that the early cessation of the rains may have prevented the dying off of seedlings through an excess of soil moisture. Too much stress, however, should not be laid on the supposed beneficial effects of this early cessation of the rains, since the rainfall figures of Gorakhpur, quoted below, show an abnormally heavy rainfall in August 1910, a year of very good natural reproduction. The normal rainfalls at Ramnagar and Gorakhpur are 62 and 48 in. respectively. This instance indicates that a period of about forty years probably elapsed between two years in which reproduction was as successful as it was in 1913.

The case of the Gorakhpur forests is also of interest. In the years 1897 and 1898 Mr. Clutterbuck was in charge of these forests, and at that time the state of natural reproduction was the cause of much concern, since, although a thorough search was made, not a single recent sal seedling could be found throughout the forests. These forests were revisited by Mr. Clutterbuck in my company in 1913, when natural reproduction in abundance was found everywhere except in certain heavily-grazed or badly-drained areas. Much of it dated from the year 1910, an exceptionally favourable seed-year in that locality, but some of it was older. The only apparent variable factor, other than climatic, which might have accounted for this sudden influx of sal seedlings, was the effect of fire-protection, but this must be ruled out, partly because fire-protection had been introduced as far back as 1875, and partly because in 1913 recent seedlings were found in abundance on burnt fire-lines and other burnt areas. The inference is that after many years of failure natural reproduction suddenly appeared in abundance owing to specially favourable climatic conditions combined with a good seed-year. The year 1910 certainly was an abnormal one so far as rainfall is concerned. The following statement gives the rainfall at Gorakhpur, month by month, in 1910 and 1911, and the normal, representing the average of forty-seven years :

Rainfall (in inches) at Gorakhpur ; normal, 1910 and 1911.

	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual total.
Normal	0·68	0·55	0·34	0·42	1·27	7·28	13·17	12·99	7·68	3·25	0·09	0·14	47·86
1910	0·30	0	0	0·03	2·63	11·59	11·34	30·13	4·57	3·35	1·30	0	65·24
1911	1·11	0	1·75	0	0·41	8·34	3·75	20·07	18·08	3·99	0·96	0	58·46

These figures show an abnormally heavy rainfall in May and June 1910, which undoubtedly created conditions very favourable to germination. Whether or not the heavy rainfall of August 1910 exerted a beneficial influence is difficult to say, but the heavy rain in November 1910 and January and March 1911 probably helped to prevent mortality from drought.

These two instances serve to indicate that local climatic conditions may be of great importance in the establishment of natural reproduction : they also indicate that the combination of an abundant seeding with climatic conditions ideal for the locality is of much rarer occurrence than might be supposed. The importance can thus be realized of taking every advantage of such favourable years as do occur for aiding the establishment of natural reproduction, where it is wanted, in areas where it does appear. A study of local climatic conditions as affecting sal reproduction in different regions would no doubt yield interesting results. It is probable that the effects vary considerably in dry and moist regions respectively. As an instance of the local effect of seasonal variation, it is reported that in the Gorakhpur district during the hot season of 1914 east winds prevailed instead of the scorching *loo*, with the result that an unusually large proportion of the seedling crop survived without having died back at all.[1]

ARTIFICIAL REPRODUCTION. As a general rule the natural reproduction of the sal is so good where conditions are favourable that artificial reproduction has not hitherto been carried out on an extensive scale. In future, however, it is likely to be carried out very largely in tracts where sal is capable of growing well but where the conditions for natural reproduction are adverse. This is particularly the case in the moist forests of the Duars, where continued fire-protection has so altered the soil conditions that natural reproduction is now out of the question throughout the greater part of the tract, and artificial reproduction is contemplated on a large scale. The afforestation of grassy blanks by artificial means has received considerable attention in recent years, particularly in the United Provinces. There is also little doubt that when more concentrated methods of regenerating sal forests become the rule, artificial reproduction will be much more general than it has been hitherto; Mr. Hole's experiments in the Dehra Dun forests show that artificial sowings on hoed ground in narrow cleared strips protected by side shade, and weeded during the first year, result in the rapid establishment of seedlings without dying back, whereas the establishment of natural reproduction in the same locality is a much slower process. This system, however, has been found to be useless in the moist forests of the Bengal Duars, where the excessive damp causes the seedlings to die off on narrow cleared lines through the forest.

In any system of artificial reproduction it is essential that fresh sal seed should be collected as soon as it falls to the ground and sown immediately, since it retains its vitality for a very short time. In artificial sowings, as in the case of natural reproduction, success must depend largely on the timely commencement of the monsoon rains unless watering can be carried out.

Various attempts in the artificial restocking of blanks with sal have been recorded in different localities in the past. The majority of these have resulted in failure or only partial success. In some cases want of success has been due to the fact that attempts have been made to restock blanks which are unsuitable for the growth of sal, or in which sal is able to establish itself slowly and only partially owing to adverse factors such as frost, drought, bad drainage, &c. The chief factors favourable to the establishment of sal seedlings have been indicated under 'the seedling': where these factors are not present sal will either fail to establish itself or the process of establishing itself will be lengthy, and success may at the best be only partial. Unless the rapid establishment of the young plants can be assured the prospects of financial success are at least doubtful. Attempts at artificial reproduction so far have included both direct sowing and transplanting, and some instances of both may be quoted.

Dehra Dun experiments. Various experiments in the artificial reproduction of sal have been carried out at Dehra Dun. Transplanting nursery-raised seedlings during the first rains with balls of earth proved quite successful. Irrigated line sowings, in which the seed was sown along the side of the water-channel and between it and the ridge of earth thrown up alongside it, gave good results, particularly where regular weeding was carried out. Unirrigated line sowings were successful if protected by regrowth of other species along either side of the line, the line itself being kept clear overhead and well hoed. If completely exposed all round the seedlings suffered from frost in the winter. Line sowings with field crops proved a cheap and easy method of raising sal, but the seedlings suffered much from frost in the winter and from drought throughout the dry season. Possibly keeping the cleared lines narrow, say 1–1½ ft. wide, and leaving high stubble on reaping the crop, might afford more protection. The crop employed was the lesser millet or *mandwa* (*Eleusine coracana*, Gaertn.). It was found better to sow the sal along lines kept clear of crops to a width of about 2 ft., the crops being sown in the intervening spaces, than to sow the crops continuously over the area; in the latter case the seedlings lacked vigour, and quickly succumbed to drought after the reaping of the crops in October.

---

[1] Annual Forest Administration Report, Eastern Circle, United Provinces, 1913-14.

Experiments were carried out with line sowings of sal between a double line of nurses sown at the same time, with the object of ascertaining if sufficient protection from frost and drought could be afforded to the sal seedlings by the nurses on either side, and if any particular nurse possessed special qualities in this respect. Seven different nurses were tried, the lines of nurses being sown 3 ft. apart, with a line of sal between them. The following observations were recorded regarding the different nurses tried: (1) *Holarrhena antidysenterica*, not sufficiently protective, the leaves falling early in the hot season and exposing the sal, which died back from drought; (2) *Mallotus philippinensis*, a good nurse where it survived, but where it suffered from drought the sal died back from drought, though subsequent growth was good; where protected by the nurse the development of the sal was good; (3) *Bauhinia racemosa*, a good nurse; where protected by the nurse the sal suffered no damage from frost, though in places along the lines where the nurse was absent the sal seedlings were killed back; (4) *Eugenia Jambolana*, unsuitable for growing in the open, as it suffers from drought itself: (5) *Eucalyptus crebra*, itself suffered a good deal from drought, but formed a sufficiently dense cover to protect the sal from frost, and proved a good nurse, the sal growing vigorously; (6) *Ougeinia dalbergioides*, growth too slow to afford protection if sown the same year as the sal; (7) *Ricinus communis* (castor-oil plant), protected the sal well from frost and drought in the first two seasons, but afterwards became too tall and lanky to be an efficient protection.

These experiments indicated that with the exception of the castor-oil plant better results would have been obtained by sowing the nurses a year or more in advance of the sal. In localities suitable for the growth of the sal, but in which the sal suffers in youth from frost or drought, there seems to be good scope for experiments in sowing it between lines of suitable nurses provided these have been introduced at least a year beforehand, in which case a distance of 3 ft. between the lines of nurses would probably be too little.

United Provinces. In the Ramnagar forest division various records exist of sowings in open grass-lands ploughed up prior to sowing: most of these have proved unsuccessful owing to damage from frost. The most important attempt was made over an area of 25 acres at Chopra on an open grassy bank on abandoned cultivation: the area is situated close to the base of the outer

Himalaya on poor soil with a subsoil consisting of a deep boulder deposit. Sal seed was sown about 1878 to 1880 in ploughed lines 15 ft. apart, and other species were sown later to fill up gaps. In the earlier years the plantation was artificially irrigated by water-channels, but the young plants were killed back by frost or drought for some years. In 1910 the lines were distinctly visible, though somewhat patchy: the trees had a height of 20 to 30 ft., which though not good for an age of about thirty years, is perhaps as satisfactory a rate of growth as might be expected in such an unfavourable locality. Sowings made at the same time on old fields at Khushkundli in the same division were more successful, the trees having attained a height of 20 to 30 ft. in fifteen years.

Sowings were made in 1907 and 1909 on deserted fields at Ghatura in the same division. The land was ploughed and the seed was sown broadcast, with the result that a thick crop of seedlings came up, and had reached a maximum height of 2 ft. in three years. The area became covered with a thick growth of grass, and the seedlings were killed back annually by frost; by 1914 they had made no appreciable progress.

The restocking of the large grassy tracts, locally known as *phantas*, in the North Kheri forests was commenced on an experimental scale in 1905, and sowings in lines have been found to give good results. The tall grass, chiefly *Saccharum Narenga*, is burnt in January or February, and the ground is hoed up in lines 1½ ft. wide and 6 to 8 ft. apart, the seeds when ripe being sown several inches apart along the lines. Weeding and hoeing along the lines is carried out for two years after sowing, in order to aerate the soil and promote vigorous growth: the area is also carefully fire-protected. The development of the young plants is by no means rapid. Sowings combined with the raising of field crops would probably give better results, but the supply of agricultural labour is insufficient to allow of this on any scale.

Transplanting nursery-raised seedlings with balls of earth has given variable results, but owing to the length of the taproot and the great care necessary in transplanting, this method is likely to prove too costly and not sufficiently successful for adoption on a large scale. The Shirpur plantation at Simaria in the Pilibhit district was formed in this way. Part of it was formed in 1893 and part in 1908. The seedlings used were pricked out twice in the nursery and transplanted when three years old: they were lifted with balls of earth about 1½ ft. deep and the protruding ends of the taproots were cut off. After transplanting the plants were for a few years watered in the dry season and protected from frost in the winter by cowls of grass. Subsequent growth is reported to have been good.

Mr. R. G. Marriott has obtained successful results by transplanting nursery-raised plants two and three years old after pruning the taproots to a length of 18 in. and the stems to about 1 in. from ground-level. The experiments were carried out in the Gorakhpur district in 1915 and 1916 with seedlings raised from seed sown in nursery-beds in 1913; over 3,000 seedlings were transplanted to the forest, and it was found that with care in transplanting success could be obtained to the extent of over 90 per cent., although no watering was done after transplanting. The best results were attained with strong vigorous plants with thick stems, their size rather than their age being the determining factor. For this reason plants three years old gave better results on the whole than those two years old. Regular weeding, loosening of the soil, and watering in the nursery, in order to stimulate vigorous growth, is thus of great advantage. The plants may be grown fairly close together, and should not be pricked out in the nursery, as encouragement should be given them to produce healthy taproots and not lateral roots.

It was found advantageous to dig the planting holes a few months in advance, say about February, in order to allow the earth dug out of them to become well aerated and to allow rain-water to enter the holes and moisten the soil below them. The best season for transplanting was found to be as early in the rains as possible, that is, as soon as the ground became thoroughly saturated by the first heavy rain. If transplanted later the plants produced weakly shoots. In transplanting the best results were obtained by digging up the plants in the nursery in the evening, pruning them, and keeping them overnight with their roots embedded in soft mud in a trench, and transplanting them in the forest in the cool of the following morning. Before planting all dead leaves should be removed from the bottom of the pit, in order to prevent the accumulation of deleterious organic matter and the sinking of the earth after being filled into the hole. While the earth is being filled round the plant it is very necessary that it should be pressed down round the roots; failure to do this was found to cause the death of the seedlings owing to their becoming loose in the holes or to the earth sinking and allowing water to accumulate in the depression so created. Subsequently it was found advisable to keep the seedlings clear of suppressing weed-growth and to loosen the soil round them periodically.

Plants pruned in this way sent up new shoots not long after being transplanted, and on being dug up were invariably found to have produced new taproots arising from close above the point of pruning. It was noticed that plants with small shoots already springing from the base of the stems grow more quickly than others, which suggests the possibility of obtaining good results by pruning down the stems some little time before removing the plants from the nursery, in order to encourage these basal shoots.

The transplanting of natural forest seedlings in the same way, after pruning their stems and roots, was also tried, but the results were far less successful than in the case of vigorous nursery-raised transplants.

So far as is known, the oldest sal plantation in the United Provinces is a small one in the compound of the club at Bareilly, which was formed in 1857. Fig. 50 shows a sal plantation 1·12 acres in area in the railway station yard at Gorakhpur. It was formed in 1887 or 1888 by transplanting young seedlings brought from the forest: these were watered in the earlier years. This plantation has been repeatedly thinned. Measurements made in the Bareilly and Gorakhpur plantations in 1916 and 1917 respectively are given below (p. **123**).

Bengal. Artificial reproduction is destined to play a very important part in the regeneration of the moist forests of the Duars, which, owing to prolonged fire-protection, have been brought to a state in which natural reproduction is impracticable. Far from being a disadvantage financially, artificial reproduction is here likely to have a great advantage over natural reproduction in that the rotation will be much more shortened, while the productivity of a very fertile forest tract will be utilized more intensively by plantations than by natural crops, in which sal is often scattered in groups of varying extent among numerous other species, many of which are of little or no value.

Two existing plantations, one in the Buxa and the other in the Jalpaiguri district, indicate the rapid rate of growth attainable by artificial crops in the Duars.

(1) Sal sowings on the southern boundary of the Buxa reserve. These sowings were made by Dr. (afterwards Sir William) Schlich between 1876 and 1880, a belt of sal 100 ft. broad being formed with the object of establishing a dense fire-belt. Measurements which I made in January 1915, the trees being then about thirty-seven years old, showed an average girth and height of 3 ft. 9 in. and 70 ft.; the maximum girth was 4 ft. 8 in. The locality here is, if anything, somewhat below the average.

(2) Sal sowings of 1896 and 1897 in the North Muraghat forest, Jalpaiguri. Two plantations, aggregating 12 acres, were formed in 1896 and 1897 by Mr. Haines and Sir Henry Farrington by direct sowing on a cleared area along with a crop of rice. The sal seed appears to have been sown in lines 10 ft. apart. In the earlier years pigs did much damage to the young plants. In the first year or two it was found advantageous to shade the plants in the hot season, and weeding and cleaning was found necessary in the earlier years in order to keep down the heavy growth of grass and weeds. For some years the plantation seems to have been lost sight of and was left untended, with the result that most of the stems became suppressed, chiefly by *Macaranga*, and in some cases they became congested for want of thinning. The plantation was in this condition when I visited it in January 1915, but the stems which had escaped suppression by *Macaranga* and had succeeded in becoming dominant showed remarkably good growth, the average girth and height of these stems being 2 ft. 5½ in. and 70 ft., and the maximum girth and height being 2 ft. 11 in. and 77 ft.; the age was then eighteen or nineteen years. This growth is probably slower than what might be expected in the case of a regularly tended and thinned plantation in the same locality. Measurements made in 1909–10, when the plantation was twelve or thirteen years old, showed an average girth and height of 1 ft. 9 in. and 55 ft., and a maximum height of 60 ft.

These two plantations indicate that if regular tending is carried out a girth of 6 ft. should be attained in the Duars in less than fifty years in localities of good quality, and in about sixty years in localities of fair quality. In natural crops, on the other hand, estimates from sample plot measurements indicate that a girth of 6 ft. is attained in 100 years in Jalpaiguri and 120 years in Buxa.

The rapid growth of artificially raised plants under favourable conditions is further exemplified in the plot of saplings in an abandoned nursery at Mendabari, measurements of which are given on p. 123 (see Fig. 41). In 5½ years an average girth and height of 9½ in. and 19½ ft. were attained; this, however, would hardly be possible in sowings on a large scale without excessive expenditure on preparation of the ground and tending. Past experiments in the moist forests of the Duars have shown that artificial reproduction cannot

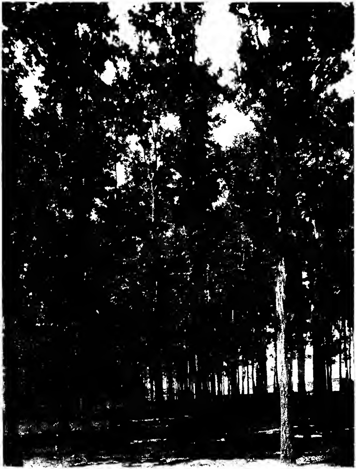

Fig. 50. Sal plantation 30 years old, Gorakhpur, United Provinces.

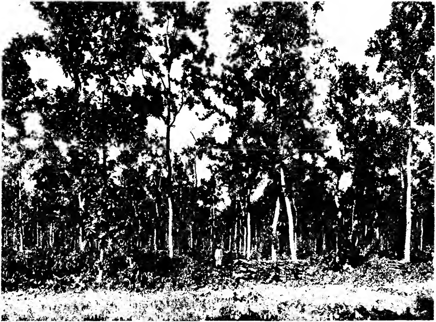

Fig. 51. Sal coppice with standards immediately after cutting of coppice, Tikri forest, Gonda, United Provinces.

be effected by any system of introducing sal into existing crops. Sowing on strips 50 ft. or more in breadth cleared through the forest, which has proved successful in Dehra Dun, has been found to be quite unsuccessful in the Duars; the seed germinates, but the seedlings die off even when kept weeded, owing to the excessive damp. Complete clearing of the forest growth, with burning of all refuse, is necessary in order to eradicate weeds and to aerate the soil. This operation can be carried out economically with the aid of shifting cultivation, and this system, somewhat on the lines of the teak *taungya* system of Burma, is now being introduced. Much experimental work remains to be done, but results so far have shown that sal sowings are not likely to be financially successful except on land actually under cultivation. That fallow grass-land can be ploughed up and successfully sown with sal has been proved, but the cost of ploughing to a sufficient extent and of subsequent cleaning to keep down the weeds has so far proved to be unduly high: if field crops are not cultivated it is found necessary to keep the ground clean by hoeing for the first two years. One of the chief dangers to be contended with in these sowings is the damage done by wild pigs, which are very destructive to the young sal plants, chiefly in the first two years: on this account careful fencing is necessary. Another source of damage is exposure to the sun in the hot season. The ground requires to be kept clear of weeds, but at the same time the young plants require side shade from the sun in the first year; experiments are in progress to effect this by leaving the stubble of the crops high on the south side of the seedlings and by heaping cut grass and weeds round the plants in order to conserve the soil moisture. It is coming to be recognized, however, that if the soil has been brought into a proper state of aeration protection from the sun is not necessary.

As regards the actual method of cultivation in the Duars, experiments carried out by Mr. E. O. Shebbeare so far have shown that the best results are attained by sowing the sal in lines 6 ft. apart, the seeds being sown as close together in the lines as their supply allows. The sal is sown with the first crop, and as many crops should be taken off the land during the first two years as possible, since this tends to keep the soil loose and to keep down the weeds. The crop found most suitable is the Garo mixture with cotton, which consists of *bhadoi* paddy, Indian corn, and cotton all sown together. After the paddy and Indian corn have been cut the cotton remains standing throughout the cold season. The Garos also put various minor crops in the mixture, such as sesamum, indigo, pumpkins, and chillies. If there is no cotton it is possible to obtain a crop of millet after the paddy is cut, and experiments in obtaining a crop of mustard are promising.

SILVICULTURAL TREATMENT. The silvicultural treatment of the sal may be considered separately under four heads: (1) coppice, (2) uneven-aged high forest, (3) even-aged high forest, and (4) tending operations in high forest crops.

1. *Coppice.* The system of coppice-with-standards has been employed more extensively in the plains forests of Oudh in the United Provinces than elsewhere, notably in parts of Bahraich, Pilibhit, South Kheri, and Gorakhpur, and in the Tikri forest of Gonda. It has also been employed to a limited extent in the Dehra Dun forests, where, however, the coppice often suffers

badly from frost. Coppice fellings are also carried out in parts of Bihar and Orissa, for instance in the Saitba working circle of Kolhan, on somewhat poor hilly ground, and in the Chandka and Khurda working circles of Puri.

In the United Provinces the tendency now is to abandon coppice-with-standards in favour of high forest. In the Dun this has been indicated by the fact that the coppice suffers so much from frost; indeed coppice must be considered an unsuitable system for sal in areas subject to any but slight frosts. In the plains forests of Oudh the system of coppice-with-standards has been largely condemned owing to the immense damage done to the standards by the abnormal drought of 1907 and 1908. During these years of drought it was noticeable that standards over coppice suffered much more than trees in high forest crops (see Fig. 45). In places also the coppice failed entirely owing to the injury done by drought to the trees coppiced not long before they were felled (Fig. 42). Another cause of failure of coppice in some localities is the fact that many of the trees coppiced have been unsound and hollow, owing no doubt to burning and maltreatment in the past.

In the Oudh forests the rotation adopted for sal coppice has varied in the past from twenty to thirty years, and the number of standards prescribed to be retained has varied from 40 to 80 per acre. Experience has shown that a rotation of twenty years, which was formerly adopted in Gorakhpur, produces poles of small size only; also that the retention of too many standards is unwise if good coppice-shoots are desired, since the standards if at all dense tend to suppress the coppice. Under ordinary conditions a maximum of forty standards per acre is probably quite sufficient.

In the Oudh coppice-with-standards coupes the young sal coppice has to contend at first with other species which shoot ahead of it. Among the chief of these are *Kydia calycina*, which may reach a height of 20 ft. in two years, *Cassia Fistula*, *Lagerstroemia parviflora*, *Grewia*, and to some extent *Terminalia tomentosa*. After some years the sal coppice overtakes these species, with the exception of the last named, which keeps fairly level with it. Hence if cleaning operations for the benefit of the sal coppice are considered necessary they can be carried out most advantageously during the first year or two. In the Tikri forest it has been found that cleanings carried out half-way through the rotation have little effect, since by that time the sal, if it has not already become suppressed, has outgrown its competitors. Figs. 51 to 55 show sal coppice-with-standards crops in different stages, and give some idea of the Oudh forests worked under this system. As a rule the coppice is easily distinguished from the standards for the first 10–15 years, but thereafter the distinction is not so apparent, and after about 20–25 years it is often difficult and sometimes impossible to distinguish the two except in the case of standards of large girth.

Details regarding the coppicing power of sal and the factors affecting it have already been given under 'silvicultural characters'.

2. *Uneven-aged high forest.* Until comparatively recently all the sal forests of India which were not worked as coppice or coppice-with-standards were treated as uneven-aged high forest and worked under some form of selection or improvement fellings. The reason usually given for adopting such fellings was that owing to past maltreatment the forests contained much

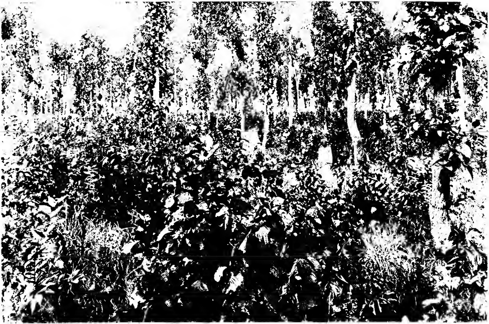

Fig. 52.—Sal coppice with standards, coppice 1 year old, height chiefly 3 to 5 ft., occasionally up to 7 ft. West Lehra forest, Gorakhpur, United Provinces.

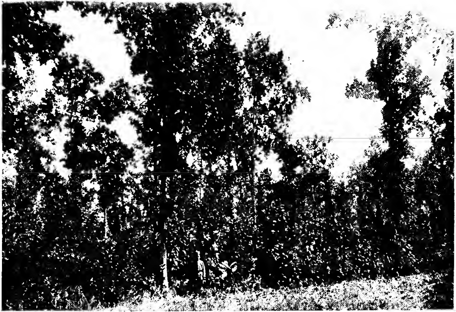

Fig. 58.—Sal coppice-with-standards; coppice 2 years old, up to 15 ft. in height. West Lehra forest, Gorakhpur, United Provinces.

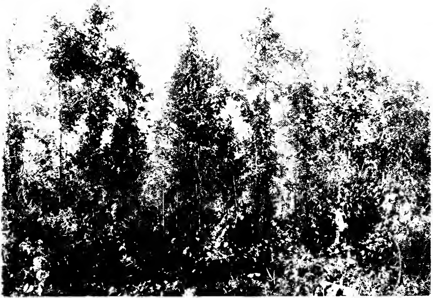

FIG. 57. *Shorea robusta* forest worked under concentrated regeneration fellings: young crop 2 years after final removal of overwood, cleaning just completed. Thano forest, Dehra Dun.

unsound, over-mature, and otherwise undesirable material which had to be removed in the interests of the future crop. So far as it goes this treatment is no doubt quite sound, but it takes account only of the existing crop, and ignores the question of obtaining sufficient reproduction. Fortunately the sal in many cases regenerates so freely that young crops would appear under almost any form of treatment, provided the canopy is opened sufficiently. On the other hand there are localities where regeneration is a more difficult matter, and selection or improvement fellings have entirely failed to secure it.

The truth is that selection and improvement fellings were adopted mainly owing to the fact that the silviculture of the sal was imperfectly understood, and they may be regarded as a provisional and temporary arrangement pending a more complete study of the habits and requirements of the tree. It will be sufficient to mention the fact that the sal was at one time looked upon as a shade-bearer and treated accordingly. We now know, as a result of the detailed experiments recorded above, and from observations generally, that this view is entirely fallacious, and that reproduction cannot be established satisfactorily unless the canopy is well opened out. The tendency of the sal to establish itself naturally in even-aged masses wherever conditions are favourable is a further reason why efforts should be made to produce these conditions and to bring up even-aged crops rather than to perpetuate systems of uneven-aged high forest which are not so well adapted to the requirements of the sal.

The selection and improvement fellings under which sal forests have been for the most part worked hitherto have been conducted on the usual selection system lines. For selection fellings a minimum exploitable girth is fixed, and the corresponding age or rotation is estimated. Each felling series is divided into a definite number of annual coupes corresponding to the number of years in the felling cycle, that is, the period during which fellings go once round the felling series. In the selection fellings the yield is fixed as a rule by number of trees, and in each annual coupe are felled sal trees of and above the minimum exploitable girth up to the number fixed for the yield. In addition improvement fellings are generally carried out with the selection fellings; these are intended to benefit the future crop by the removal of inferior species and otherwise undesirable stems interfering with promising stems of sal and other valuable species. Where improvement fellings only are prescribed, the yield is fixed by area.

In the working plans of the United Provinces the exploitable girth usually adopted has been 6 ft., the corresponding rotation varying from 120 to 150 years, and the felling cycle varying from 15 to 28 years. In Bengal the exploitable size has been fixed as a rule at 6 ft. girth or 2 ft. diameter, with a rotation varying from 100 to 150 years. In Assam an exploitable girth of 6 ft. has been in force in Goalpara and Darrang, the rotation being 120 years, and the felling cycle 15 years and 5 years in the two localities respectively. In Bihar and Orissa the Singhbhum forests have been worked under the selection system with yield by area; the exploitable girth has been 6 ft., the rotation 180 years, and the felling cycle 30 years. In the Banpur working circle of Puri an exploitable diameter of 2 ft. has been adopted, with an estimated rotation of 120 to 150 years; the yield is by number of trees. In the Central

Provinces the exploitable girth usually adopted for selection fellings is 6 ft., the estimated rotation being 170 years; in most cases the felling cycle is 30 years. In the Khannat sal forests of South Mandla the exploitable girth is fixed at 5 ft.

3. *Even-aged high forest.* In order to produce successive age-gradations of even-aged crops, for which the sal is best adapted, some system of concentrated regeneration is necessary. The general outline of such a system is the one applicable to the conversion of irregular forest crops of any kind, such as those usually found throughout India, into even-aged high forest crops. The general scheme is to divide the ascertained rotation into a number of regeneration periods and to divide the forest area into a similar number of periodic blocks. One periodic block, usually termed block I, is selected for regeneration during the period, while subsidiary fellings of the selection type, with thinnings, are prescribed over the remainder of the area under a definite felling cycle. Under this system each block is regenerated in turn, until by the end of the rotation a series of more or less even-aged crops is obtained. It is not always necessary, or even advisable, to allot all the blocks to periods, but in some cases it may be advisable to allot at least some of them.

The general outline of the scheme is simple enough, but the allotment of crops to periods may present difficulties if the forests are in a very abnormal condition. In the case of the sal it is generally advisable to allot to periodic block I those compartments which contain a large quantity of established natural reproduction which is in need of freeing; this is particularly advisable in localities where the steps necessary to obtain reproduction have not been sufficiently determined by experiment. In addition, however, it may be necessary to allot for regeneration areas which contain little or no established reproduction, and it is here that difficulties will be encountered and the factors of the locality will require careful study. The various factors which influence the reproduction of sal, and the measures necessary to secure its establishment, have already been described in some detail so far as they are known at present. The more important considerations involved may be recapitulated briefly:

1. Favourable or unfavourable soil conditions are indicated by the growth of certain plants, notably grasses, of which *Saccharum Narenga* is an indicator of favourable conditions.

2. As regards seed-bearers, the size and soundness of the trees appears to have no effect on the fertility of the seed, though trees with well-developed crowns may be expected to produce seed in greatest quantity. Seed-years are fairly frequent in most localities, but a combination of prolific seeding with favourable climatic conditions is of rarer occurrence than might be supposed. The fruits ripen chiefly in June, and are ordinarily carried to a distance of 50–100 yds. from the tree, though possibly an espacement of more than about 50 yds. between seed-bearers, giving a radius of seeding of 25 yds., should not be relied on to produce a plentiful crop of seedlings.

3. A thick layer of dead leaves has an adverse mechanical effect in entirely preventing germination in the open, while in the shade it produces shallow-rooted seedlings which succumb after the first rainy season; the removal of a layer of dead leaves, by burning or otherwise, is therefore an advantage where reproduction is desired.

4. Germination takes place under fairly dense shade, but the resulting seedlings do not survive, primarily owing more to an unfavourable soil factor than to the direct effect of shade.

5. An important consideration in the establishment of reproduction is the dying back of seedlings, which is due to various adverse factors such as bad soil-aeration in the rainy season, drought in the dry season, frost in frosty localities, and mechanical injury from animals, insects, fire, &c. In the case of the first two factors the remedy is to promote vigorous growth, particularly of the taproot, in the first rainy season: this goes a long way towards ensuring the survival of the seedling in the subsequent dry season. In the sal forests of the semi-moist type of Dehra Dun and many other localities with a loamy soil this can be effected by digging up the soil, removing the dead leaves by burning or otherwise, completely removing the overhead canopy, and weeding the young crop.

6. Where frost or drought are to be feared, protection from the side is of more value than overhead cover: it has been found that overhead cover which is dense enough to cause the suppression of young sal plants may be insufficient to protect them from injury by frost. In the Dehra Dun forests excellent reproduction has been obtained by clear felling in patches or strips not more than 100 ft. and preferably not more than 60 ft. wide, removing dead leaves, digging up the ground, sowing sal seeds, and weeding the seedlings during the first season. The most favourable direction of strip fellings has yet to be determined, and it may possibly be found to vary locally. In Europe lateral protection from the morning sun, that is, from the south-east, is perhaps the most effective in preventing damage from frost; in the Dehra Dun forests complete protection was obtained on a cleared strip running ENE. to WSW.

7. The opening of the canopy, however, will not effect the establishment of natural reproduction in all types of forest. In the very moist types found in the Bengal Duars and Assam the admission of light produces a rank growth of weeds and climbers, which prevents the establishment of reproduction (see Figs. 47 and 48). In the semi-moist types found throughout the greater part of the United Provinces and elsewhere, other conditions being favourable, the admission of light sufficient to cause a moderate growth of grass will induce the appearance of sal reproduction, the establishment of which depends on a drastic opening of the canopy.

8. In dry forests where reproduction is difficult to obtain two methods have been suggested with the view of preserving the soil-moisture, (*a*) the introduction of an underwood as a soil-protection, and (*b*) cultivation of the surface soil, accompanied if necessary by mulching in the dry season and the construction of trenches and small embankments in order to arrest the run-off of water.

9. In the case of mechanical injury from fire, grazing, &c., which prevents the establishment of reproduction, protective measures are necessary. Mere closure to grazing may be sufficient to induce good reproduction, but where the soil has become hardened by trampling, thorough digging up of the soil, accompanied by a severe opening of the canopy, has proved effective in producing conditions favourable for reproduction.

These are some of the main considerations involved in devising means of regenerating definite blocks of forest with the object of producing even-aged crops. The advisability of taking advantage where possible of existing young crops already established on the ground, and freeing them from overhead cover, cannot be emphasized too strongly: this important step should be taken as a primary measure, efforts to induce the appearance of new reproduction being considered as supplementary. In this connexion there is little doubt that artificial reproduction will be more largely resorted to in the future than has been the case in the past. In certain types of moist forest it will be impossible to obtain satisfactory reproduction in any other way than by clear-felling, burning, and regenerating artificially, preferably by the aid of temporary cultivation with field crops; this applies not only to the moist forests of the Duars, but also to moist types found in other localities, for instance in fertile valleys and ravines where any opening of the canopy is at once followed by a dense growth of weeds and climbers. The restocking of grassy blanks furnishes another instance where artificial reproduction may have to be resorted to on a large scale.

The degree to which the canopy should be opened in order to stimulate sal reproduction, and the manner in which the opening should be carried out, are matters of great importance which must be decided by local experience. The excellent reproduction found throughout a considerable portion of the Singhbhum forests is attributable in many cases to heavy fellings carried out for the production of sleepers in 1895 and subsequent years. It is proposed to introduce concentrated regeneration fellings in these forests, and over considerable areas these fellings will consist of nothing more than the removal of the overwood over young crops already well established. In the high-level forests of North Kheri in the United Provinces some of the finest pole crops now existing are to be found in areas where heavy fellings were carried out many years ago. In the neighbouring district of Bahraich an experiment in the drastic opening of the canopy was carried out about 1885 at Tigra well. Only about twenty trees per acre were left, the remainder being felled. The result was that over a considerable portion of the area reproduction failed, a sea of grass resulting. In some places, however, vigorous and extremely dense pole crops of sal have resulted. In all probability these crops arose from natural reproduction already on the ground, in which case this experiment would show that whereas the removal of the canopy greatly stimulates the growth of young sal crops, it cannot be relied on in itself to effect the establishment of new reproduction, and may result in nothing more than a heavy growth of grass.

The question of opening the canopy in the form of fellings in clear narrow strips has already been alluded to in connexion with Mr. Hole's experiments in the Dehra Dun forests. The experiments of 1915 were carried out in a particularly unfavourable year, owing to the heavy rainfall in August and September and an unusually hot dry season following. Sowings in the open without side shade resulted in only 2 per cent. of healthy seedlings at the close of the year, sowings in the shady forest resulted in 6 per cent., while sowings in cleared lines and patches 60–100 ft. wide resulted in 36 to 42 per cent. A clearing 180 ft. square gave only 26 per cent. of successful seedlings, which indicates that in these forests an opening more than perhaps 100 ft. wide is not advisable. The local application of strip fellings in actual practice will involve (1) ascertaining by trial the direction of strip which promotes the most successful establishment of reproduction, with the aid of side protection if required, (2) laying out comparatively narrow cutting sections, if possible with their long sides parallel to the strips, and (3) working completely through these cutting sections during the regeneration period by successive parallel strip fellings, the intervals of time between the successive strip fellings being long enough to enable the young growth to become sufficiently tall to escape damage from ordinary frosts. The regeneration period should be long enough to enable the young growth in the first strip to reach a height sufficient to afford protection to the strip which will be felled at the end of the period in the adjoining cutting section. To take an example, with a regeneration period of 30 years, intervals of 10 years between successive strip fellings, and strips 60 ft. wide, the width of the cutting sections would require to be 180 ft. Alternatively shelter belts may be left between the cutting sections to be felled and regenerated later, or the cutting sections may be placed in different periods, but neither of these alternatives is to be commended if they can possibly be avoided, owing to the diffusion of work and complication which they would entail.

It is many years since the value of side protection from frost, as obtained by fellings in narrow strips, was discovered in the case of the sal. Writing in 1885,[1] Captain E. Wood, Conservator of Forests in Oudh, described experiments carried out in the coppice forests of Bhira, where somewhat severe frosts are experienced. These plots were coppiced : (1) two acres completely cleared, (2) two acres cleared in strips 20 ft. broad, leaving alternate strips 20 ft. broad untouched, (3) one acre cleared of about half the stock, the remainder being left in the form of standards. In plot 1 the first severe frost greatly damaged the coppice-shoots, in plot 2 the shoots grew up straight and were untouched by frost, while in plot 3 they suffered from suppression by the standards.

In the Central Provinces also strip fellings have apparently been tried with success. In the Lormi range working plan, Bilaspur, 1898, it is stated : ‘ Clear strip fellings have been tried in this division with very excellent results.’

Mr. Hole’s experiments in the Dehra Dun forests have revealed the fact that the direction in which cleared strips run has a very decided influence on the establishment of the young crop. He found that in years of heavy rainfall side shade on the south is injurious in keeping the soil continually moist and causing the plants to suffer from bad soil-aeration and from the attacks of leaf fungi. He advocates, therefore, that in localities in northern India with a normal rainfall of 50 in. or more during the period June to September inclusive the strips should run in a true north and south direction, thus ensuring shade on the area in the morning and afternoon and full sunlight in the middle of the day, which will prevent an excessive accumulation of moisture in the soil. Under such conditions the system he advocates for regenerating a given area is to divide it permanently into a series of narrow strips running north and south, the width of the strips being about three-fourths the height of the surrounding forest crop. Every alternate strip will be clear-felled, hoed up, and sown thickly with sal seeds, not less than six seeds to the square foot.

---

[1] Ind. Forester, xi (1885), p. 436.

the resulting young crop being weeded as often and as long as may be found necessary. In the case of narrow clearings, where weeds are less abundant than on wide clearings, one weeding at the end of the first rains and one at the end of the second rains has been found sufficient. When the young crop has attained full height-growth the intervening strips will be felled and regenerated in the same way. He estimates that the time required to produce a full crop of established seedlings $3\frac{1}{2}$ ft. high on a strip treated in this way will be five years, while a similar result could not be obtained by a system of regeneration under a shelter wood, supplemented by the clearing of dead leaves from the surface of the soil, in less than forty-eight years.

This system is not intended to apply to open poorly-stocked areas, or to localities where bad soil-aeration is not a factor of importance, or where there is no fear of frost damage, as in the Duars or Assam, where large clearings are possible. The system is intended to apply to average well-stocked sal forest on loam, in places where frost damage is feared, where dying back is a marked characteristic, and the establishment of seedlings is slow and uncertain: such conditions are probably met with in the bulk of the forests of the central and north-western regions of the sal. In dry types of forest, however, shelter from the south may possibly prove advantageous, though experiments to ascertain this are necessary.

There is still abundant scope for experimental work in ascertaining the best direction for clear strip fellings and for side protection, if required, in different localities and under different conditions. It would simplify working if it were found sufficient to protect the clear strips not on both sides, as in the case of the proposed system of alternate strips, but on one side only, for then the fellings could be made to progress continuously in one direction, as in the usual strip system, with the object of regenerating a given area in a definite period of time. Some examples may now be quoted of systems of concentrated regeneration actually applied to or proposed for sal forests in different localities.

The Thano forest near Dehra Dun, 4,883 acres in extent, on flat to gently sloping ground, has been under concentrated regeneration since 1903, and the prescriptions were completely revised in 1911.[1] The rotation fixed at present is 144 years, which is estimated to produce trees 6 ft. in girth: the rotation is divided into six regeneration periods of twenty-four years each. The state of the crop, which is more or less homogeneous throughout, has made it possible to adopt compact self-contained periodic blocks. The crop consists of well-stocked sal forest subject to frost on the lower ground, but free from it in the upper parts. Natural reproduction is well established throughout almost the whole area, and the regeneration fellings consist merely in removing the overwood from over the young crop. This is being done in two fellings at intervals of twelve years, the idea being to retain part of the overwood as a protection against frost. The yield is fixed by area, definite annual coupes being allotted. In the first felling the aim is to remove about half the overwood, though this is not rigidly adhered to. The degree of removal varies with the state of the young crop: where the latter is well established it is completely freed, otherwise sufficient seed-bearers or protective cover are

---

[1] Working Plan for the Thano Forest, R. S. Troup, 1911.

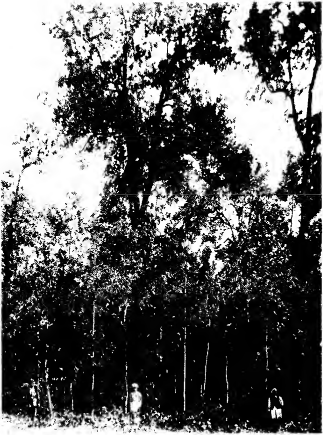

FIG. 56. *Shorea robusta* forest worked under concentrated regeneration fellings, immediately before final removal of overwood; young even-aged crop well established; Thano forest, Dehra Dun.

retained until the second felling. Ordinarily the maximum limit of girth of well-grown young trees retained to form part of the future crop in the regeneration fellings is 2½ ft., so that for a time the young crop in places has a somewhat uneven appearance. Cleanings and cutting back operations are carried out in the young crop. It is probable that in future revisions of the working plan the removal of the overwood will be prescribed in one instead of in two fellings, as the overwood left is no protection against frost, while the second felling causes much damage to the young crop. Only where frost damage is severe will it probably be necessary to retain side shelter and fell in strips.

The subsidiary fellings in blocks II to VI are selection and improvement fellings. These blocks are definitely allotted to periods, and the fellings are so carried out as to favour in each block the trees which will ultimately form the final crop. The girth limits of trees to be favoured specially are: block II, 3 ft. 6 in. to 6 ft. 6 in.; block III, 2 ft. 6 in. to 5 ft. 6 in.; block IV, 1 ft. 6 in. to 4 ft. 6 in.; block V, 0 ft. 6 in. to 3 ft. 6 in.; block VI, 0 to 3 ft. 0 in.

Fig. 56 shows a crop in periodic block I immediately before the final removal of the overwood, with a well-established even-aged young crop on the ground. Fig. 57 shows a regenerated young crop two years after the final removal of the overwood; a cleaning has just been completed.

Concentrated regeneration fellings have recently been introduced in the *bhabar* forests of the Haldwani forest division of the United Provinces.[1] The rotation adopted is 120 years, corresponding to an average girth of 5 ft. This rotation is divided into six regeneration periods of twenty years each, but regenerative operations are actually spread over a double period of forty years in two stages: (1) twenty years in the preparatory stage, the work consisting of light fellings, extensive soil preparation and cultural operations, and (2) twenty years in the secondary stage, comprising the removal of the overwood and the completion of regeneration. Crops in the latter stage are allotted to period I, and those in the former stage to period II. The allotment of crops to periods has been made according to the condition of the various crops, and the treatment prescribed in each case is as follows:

(*a*) Period I. Crops in which there is much mature overwood and much natural reproduction: these have passed the preparatory stage and have reached the secondary stage.

(*b*) Period II. Crops in which there is much mature overwood but very little natural reproduction: these are ready for the preparatory stage, and the operations will consist of preparation of the soil, cleanings, and the burning of the leaf-layer in good seed-years.

(*c*) Periods III, IV, and V. Middle-aged crops: the treatment will be light improvement fellings and thinnings under a felling cycle of ten years.

(*d*) Period VI. Crops in which the overwood is very sparse, but in which there is a uniform underwood of poles and saplings, the operation prescribed being the removal of the thin overwood; no further regeneration will be carried out.

The yield is fixed by volume in periodic block I, and by area in the other periodic blocks. In the former case, however, reasonable elasticity is permitted, and the utmost freedom is allowed in executing the fellings, which may be made in the form of groups, or uniformly, or otherwise as the conditions of each case may require. In order to ensure that the whole of periodic block I is visited at frequent intervals it is divided into four sub-blocks, and the fellings go round these in a felling cycle of four years.

---

[1] Revised Working Plan for the Forests of the Haldwani Division, United Provinces, J. V. Collier, 1914.

A concentrated system of working has recently been introduced for some of the sal forests of the Ramnagar division, United Provinces, though the area to which this system is to be applied at present forms only a small proportion of the total area of the division, and contains more or less pure sal forests, often even-aged, occupying flat or gently sloping ground in the outer valleys.[1] Such forests are comprised in the uniform working circle, the area of which is 14,118 acres.

It is proposed for the present to adopt a rotation of 120 years and a regeneration period of 40 years. Woods will be allotted to two groups, as follows:

Group A. Woods to be regenerated during the next 40 years. Actually many of these areas will probably be regenerated completely in half this time, as they contain much regeneration. Normal area $= \frac{1}{3} \times 14{,}118 = 4{,}706$ acres: actual area $= 3{,}348$ acres.

Group B. Woods not to be regenerated during the next 40 years. Normal area $= \frac{2}{3} \times 14{,}118 = 9{,}412$ acres: actual area $= 10{,}770$ acres, nearly all consisting of crops estimated to be 1 to 40 years old, with the age-classes in a very abnormal condition.

The order of allotment of the older woods to group A is made theoretically in the following order, the compartments being classified accordingly:

1. Compartments partly regenerated, where fellings must be continued.
2. Those in which the growing stock has deteriorated so much that it is advisable to regenerate them at once.
3. Those containing much over-mature stock in which the trees are deteriorating.
4. Those containing much over-mature stock in which the trees are still healthy.
5. Mature crops.
6. Crops almost mature.

The yield is fixed by area, and silviculture has full play. The following are the more important details regarding groups A and B respectively:

Group A. Regeneration fellings will be undertaken with the object of starting, carrying on, and completing regeneration. The forests of this group are comprised in one felling series, divided into five annual coupes, this number being a submultiple of the period for which the plan is framed: these coupes have been fixed in such a way as to furnish as nearly as possible an equal annual out-turn, for which purpose an enumeration of the older age-classes was carried out. Felling rules are not enunciated in detail, and must vary in different places: all fellings in group A, however, will be carried out for the purpose of regenerating the area, preference always being given to the young crop as opposed to the old one.

---

[1] Working Plan for the Ramnagar Forest Division, S. H. Howard, 1917.

Group B. This group is divided into ten annual coupes, this number being a submultiple of the period of the plan, and the operations consist of thinnings, including the removal of inferior species and of the overwood remaining over young poles and other stems, an operation which will be particularly necessary during the earlier years of the rotation. A classification of thinnings is given in an appendix to the working plan. Briefly they will be conducted thus: (*a*) crops whose principal height-growth is not complete, moderate or heavy ordinary thinnings; (*b*) crops whose principal height-growth is complete, crown thinnings, at first light but becoming progressively heavier as the age increases. On no account will regeneration fellings be made in group B, the fellings being entirely in the interest of the existing crops, which consist largely of poles.

The period of the plan is twenty years, but it has been recommended that a revision be made after ten years. At each revision the rotation, the allotment of crops, and other matters will be entirely reconsidered according to the condition of the crops at the time, and in the light of further experience: in addition new areas now outside this working circle may possibly be brought into it.

The Gorakhpur forests of the United Provinces are situated on flat ground. Until recently the more accessible blocks have been treated under coppice-with-standards and the remainder under light improvement fellings. Under the latest working plan [1] a system of high forest with concentrated regeneration fellings has been introduced. The management is simplified by the fact that frost is negligible, while natural reproduction is already present in quantity, particularly in the areas hitherto worked under coppice-with-standards, except in certain areas of comparatively small extent, where it has failed owing to illicit grazing, with the consequent hardening of the soil, want of surface drainage, a dense carpet of leaves at the time the seed falls, and want of light. Experiments have shown that on such areas a young crop can be obtained successfully by opening the canopy, fencing against grazing, hoeing the soil, burning the layer of dead leaves, and sowing sal seed. The planting of strong nursery plants with stem and root pruned down also gives promise.

The treatment prescribed in the areas previously worked as coppice-with-standards consists of nothing more than a clear-felling in the nature of a final felling over a regenerated crop, and the new crop will consist partly of coppice and partly of seedling growth. The fellings will be carried out in annual coupes, and will be followed by repeated cleanings in the young crop; the produce of these cleanings is saleable owing to a keen demand for small material. In places where natural reproduction fails, artificial aid will be resorted to. The rotation adopted tentatively is one of forty years, the aim being to produce fair-sized poles.

In the areas previously worked under light improvement fellings there is often much suppressed reproduction, but the fellings have been too light to produce a vigorous young crop. Here provisional treatment under improvement fellings for the removal of overmature and unsound stems is prescribed for a preparatory period of ten years, during which regenerative measures will at the same time be commenced in those portions which it is intended to place in periodic block I at the end of this preparatory period, when in all probability the treatment applied will be similar to that now applied to the areas formerly worked under coppice-with-standards. The regenerative measures to be commenced during the preparatory period will be the freeing of advance growth and the stimulation of further reproduction in the manner indicated above. The rotation has not yet been fixed.

---

[1] **Working Plan for the Forests of the Gorakhpur Division, United Provinces, R. G. Marriott, 1915.**

The case of the sal forests of the Duars presents problems of a special nature demanding very special treatment. These forests have already been described above (pp. 70–73). They had their origin in burnt savannah tracts, but continuous fire-protection for some decades has entirely altered the character of the undergrowth, which now consists largely of a dense mass of evergreen shrubs, herbaceous plants, and climbers. Not only has sal reproduction been entirely suppressed, but the altered soil conditions, in the shape of bad aeration due to increased moisture, have rendered it impossible for sal seedlings to establish themselves in spite of intensive cleanings. Experimental fellings, burning, cleaning, and artificial sowings in cleared strips through the forest have proved of no avail, and it is evident that until the condition of the soil has been radically altered, it will be impossible to raise young crops of sal. This, it is known from past experiments, can be effected by clear-felling, burning the refuse, cultivating the soil, and raising crops of sal by artificial means. It has therefore been decided to adopt the system of clear-felling followed by artificial reproduction with the aid of field crops. The results of past sal sowings indicate that great success can be attained by artificial reproduction in this way. In the Duars frost is practically unknown, and if sown on prepared ground in the open, sal seedlings do not die back, but grow rapidly from the start. A sal plantation in the Jalpaiguri district formed by sowings with the aid of field crops had a mean girth of nearly 2½ ft. and a mean height of 70 ft. at an age of 18 to 19 years. On the basis of this and other artificially raised crops it is estimated that trees 6 ft. in girth can be produced by sowings in the open in 50 to 60 years as against 100 to 120 years in the case of natural forest, and the financial gain consequent on the shortening of the rotation and the more complete stocking of the area will be very considerable. For the present, however, it has been decided to adopt a rotation of 80 years, partly for the sake of safety and partly because it is not certain that labour will be available for cultivating and stocking the larger area to be regenerated under a shorter rotation. This rotation will be divided into four regeneration periods of 20 years each. Theoretically this formation of periods would be unnecessary if ample labour could be relied on for the clearing and restocking of a definite area annually; this, however, is not the case at present, and a commencement will be made in regenerating as much as can be dealt with annually with the labour available, the area regenerated annually being gradually increased as labour becomes more plentiful, with the object of completing the regeneration of one-fourth of the whole sal-producing area in 20 years. The areas allotted to periodic block I are those containing least sal: the other periodic blocks will be worked under selection and improvement fellings on a felling cycle of 20 years until their turn comes for regeneration. The establishment of numbers of forest villages for the purpose of carrying out the works of reproduction and tending will necessitate the creation of many different felling series. So far the work has been purely experimental, and this will probably continue to be the case for some time to come. Some of the results already obtained have been described above (p. 109). A special feature of this system of artificial restocking of clear-felled areas in the Duars is that in order to obtain labour to carry out the temporary cultivation required in connexion with the raising of sal crops, it is necessary to provide the villagers with a certain area of wet cultivation, to the extent, at present, of a maximum of 3 acres per house. This reduces the forest area available, but in spite of this the actual quantity of sal produced per acre over the whole area will be very much larger than it has been in the past, owing to the more complete stocking of the sal crops.

The treatment just described will be applied for the present only to the low-level moist sal forests of the Duars. Want of labour prevents its immediate extension to the waterless high-level tracts which are characterized by a dense undergrowth of *sau* grass (*Pollinia ciliata*), and here annual burning will be carried out in the hope of replacing it by savannah grasses in which sal has more chance of regenerating naturally. If sufficient labour becomes available in future, however, it is not improbable that the system of clear-felling with artificial reproduction may be adopted ultimately.

4. *Tending operations in high forest crops.* The first operations necessary in the treatment of young sal crops are cleanings, which consist in freeing the young sal from weeds, from faster-growing inferior species, and from climbers. As a rule the first cleaning is carried out the year after the main felling, and at the same time damaged or misshapen sal saplings are cut back to near ground-level with the object of causing them to produce straight coppice-shoots: this cutting back operation is of great importance. Recently in the United Provinces experimental cleanings have been carried out two years before the main felling, the object being to prevent coppice regrowth of fast-growing inferior species owing to the shade of the canopy. These experiments have proved highly successful, and it is proposed to extend considerably the system of carrying out cleanings two years before the fellings. In this case the cutting back of badly shaped and damaged sal saplings will still be necessary after the fellings. Cleanings are repeated as long as and at such intervals as may be found necessary.

Thinnings constitute an important operation in the tending of sal crops, although opinions differ as to the intensity with which they should be carried out. That girth increment is stimulated by thinning requires no demonstration. The precise effect on the volume increment per acre of thinnings carried out to different degrees of intensity is under study in numerous sample plots, but these have not yet been under observation long enough to produce detailed results. But in any case such figures must often be of merely academic interest, since thinnings in sal crops should naturally be carried out under the ordinary rules of silviculture, and in this respect the sal does not differ materially from other gregarious species which tend to form dense crops. Generally speaking, it is not held to be advisable to thin sal crops too heavily until the time arrives for opening the canopy for regeneration. It is often necessary, however, to thin existing crops more heavily than would otherwise be advisable in order to remove inferior species and damaged or otherwise undesirable sal stems interfering with more promising stems. Where cleanings have been carried out properly in young crops, and light thinnings have been commenced early, there should ordinarily be no cause for thinning too heavily at a later stage: under systems of concentrated regeneration matters will be much simpler in this respect than is the case with the majority of the sal crops now existing.

RATE OF GROWTH AND OUT-TURN. 1. *High forest.* The rate of growth of the sal cannot be ascertained with any degree of accuracy by counting rings on stumps, as the rings are not as a rule clearly distinguishable. Numerous sample plots have been under measurement for some years in a number of forest divisions; in every case the object of these divisional sample plots has been to ascertain the girth increment. In 1910–11 a beginning was made by the Forest Research Institute, Dehra Dun, in the establishment of sample plots in even-aged more or less fully stocked sal crops in different parts of the country, and a large number of these plots, which are remeasured quinquennially, have been established in various types of forest. These Research Institute plots have for their object the determination, among other matters, of girth, height, and volume increment, and of the yields obtained from periodic thinnings. So far these plots have not been in existence long enough to furnish results of a reliable nature, though in course of time the statistics yielded by them should prove fairly comprehensive. Some of the results of measurements made hitherto in these plots are given on pp. 124–127, but as these are based on measurements extending over five years only, they may be accepted as nothing more than provisional.

(a) *Girth increment.* The table on pp. 124–127 gives a series of girth increment figures, based chiefly on the results of measurements in divisional and Research Institute sample plots. As most of the plots in question have not been thinned, and in the case of the divisional plots in particular vary much in density, the figures do not form a good basis for comparative purposes: they are, however, the best obtainable at present. Most of these figures have already appeared in the published statistics issued by the Silviculturist at the Forest Research Institute, Dehra Dun.[1] With the exception of the plantation figures for Buxa and Jalpaiguri in Bengal, all these statistics refer to natural crops. In the case of the plantations the exact age is known. In the case of the natural crops nothing has been added for the time required for a seedling to establish itself; strictly speaking, therefore, a considerable number of years should be added to the estimated ages as shown.

It should be noted that the figures in the table in question show the estimated rate of growth under past conditions, that is, the crops have in the great majority of cases not been thinned or tended in any way. Properly tended crops would no doubt show a faster rate of growth. Another point to note is that in uneven-aged crops the rate of growth has been calculated not only from the larger and dominant stems, but also from the smaller or dominated stems, all the measurements for one plot being combined; even though badly suppressed stems have been left out of account, figures so compiled do not correctly represent the rate of growth of a dominant even-aged crop such as correct silviculture should aim at. Most of the divisional sample plots contain trees of widely different girths, and many of the smaller stems on which the rate of growth is estimated must have been suppressed for years. The Research Institute plots are laid out in even-aged crops, and the error in the case of these is probably not so great, but none of these plots have yet been tended regularly for a sufficient length of time to produce the best stem development.

---

[1] Ind. For. Records, vol. vi, pt. ii, 1917, and pt. v, 1918.

The excessively slow growth in the natural crops of Mandla and Balaghat in the Central Provinces may be contrasted with the rapid growth in the plantations of Buxa and Jalpaiguri in Bengal. That trees artificially raised and tended are capable of rapid growth may be seen from the following measurements made by Dr. Brandis in 1863 in respect of trees of known age at Saharanpur and Calcutta :[1]

Saharanpur,	age 13 years,	girth 27 in.	(mean of 33 trees)
,,	,, 30 ,,	,, 54½ in.	
,,	,, 35 ,,	,, 79½ in.	
Calcutta,	,, 25 ,,	,, 69 in.	

The rapid growth of artificially raised sal in the Bengal Duars is shown in the case of a small plot in an abandoned nursery bed at Mendabari in the Buxa district. Seed was sown in June 1911, and the resulting seedlings grew rapidly, without dying back, into a dense clump of saplings. In January 1915 these were thinned out, 43 saplings being left. The following measurements have been recorded for this plot :

Shorea robusta : measurements of artificially raised saplings, Mendabari, Buxa.

Date.	Age.	Girth.		Height.		Remarks.
		Mean.	Maximum.	Mean.	Maximum.	
	years.	in.	in.	ft.	ft.	
January 1915	3½	5·5	8·4	14	16	43 stems after thinning.
December 1916	5½	9·5	13·5	19·5	25	Excluding 7 suppressed stems.

This plot is shown in Fig. 41.

In 1918 Mr. Marsden formed the following estimate, based on the results of measurements in 61 sample plots in even-aged crops, of the girth increment of sal in the United Provinces, arranged in two tentative quality classes :

Shorea robusta : girth increment in even-aged high forest crops, United Provinces.

Girth.	Corresponding age.	
	I quality.	II quality.
ft.	years.	years.
1	29	37
2	42	56
3	56	77
4	72	105
5	92	—

---

[1] For. Flora, p. 27.

Shorea robusta: rate of growth in girth, deduc

Province	Forest division.	Approximate rainfall. inches.	Particulars.		
United Provinces.	Dehra Dun	80–85	Divisional plots.		Fastest growth, unthinned, **Malhan range**, foot Siwaliks.
					Slowest growth, unthinned, **Malhan range**, near Jhajra.
					Mean of 7 unthinned plots throughout the Dun.
	Saharanpur	50	Divisional plots.		Fastest growth, unthinned, Dholkhand, No. 1.
					Slowest growth, unthinned, **Lakarkot**, No. 2.
					Mean of 7 unthinned plots.
			Research Institute plot in dry hill type, unthinned, reaching small dimensions only.		
	Haldwani	70–80	Research Institute plots		No. 6. Fastest growth, unthinned. Sal forest of very good quality.
					No. 1. Slowest growth, unthinned. Pure uniform pole crop, fully stocked; plateau foot of hills; soil sandy loam with small boulders.
					Mean of 7 unthinned plots.
	Pilibhit	50–55	Divisional plots.		Fastest growth, unthinned, Banbasa compartment V.
					Slowest growth, unthinned, Neoria compartment XV.
					Mean of 9 unthinned plots.
					Mean of 2 thinned plots.
			Research Institute plot. Forest of somewhat poor quality, unthinned: density 0·8.		
	North Kheri	50	Divisional plots.		Fastest growth, unthinned, high-level forest. West sal working circle compartment 9 *b*.
					Slowest growth, unthinned, *phanta*-belt type, of good height-growth, West sal working circle compartment 30.
					Mean of 5 unthinned plots.
			Research Institute plots.		No. 7. Fastest growth, unthinned, high-level forest of good quality. [*Note.* Some plots showed faster growth, but figures available up to 60 years only.]
					No. 5. Slowest growth, unthinned, low-level *phanta*-belt type of good quality.
					Mean of 10 unthinned plots.
	South Kheri	45	Divisional plots.		Fastest growth, unthinned, Gola working circle coupe VIII.
					Slowest growth, unthinned, Kishenpur working circle coupe VI.
					Mean of 8 unthinned plots.
	Bahraich	42–45	Divisional plots.		Fastest growth, unthinned, Murtiha II.
					Slowest growth, unthinned, No. 1, Nishangara 1.
					Mean of 9 unthinned plots.
			Research Institute plots, mean of 5 unthinned plots, growth somewhat similar in all.		
	Gonda	55–60	Research Institute plots.	Thinned.	Fastest growth, plot No. 6, forest of very good quality, heavily thinned.
					Slowest growth, plot No. 8, forest of very good quality, moderately thinned.
					Mean of 3 thinned plots.
				Unthinned.	Fastest growth, plot No. 5, forest of very good quality, adjoining No. 6, above.
					Slowest growth, plot No. 7, forest of very good quality, adjoining No. 8, above.
					Mean of 3 unthinned plots.

om measurements in high forest sample plots.

o. of measurements.	Age in years. 20	40	60	80	100	120	140	160	180	200	220	240	260
	Corresponding girth at breast height.												
	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.
100	1 0	1 9½	2 7	3 5	4 3	5 1	5 11½	..	..	..	..	..	..
248	..	0 7½	1 1	1 7	2 1	2 6½	3 0½	3 7½	4 3½	5 1½	5 11½	..	..
1680	0 8	1 4	1 11	2 6	3 2	3 10	4 7	5 4	6 0	6 9	..	..	..
149	..	0 8½	1 2½	1 9½	2 4½	3 0	3 8	..	..	..	..	..	..
18	..	0 4½	0 7½	0 11	1 2½	1 5½	1 9	2 0½	2 4	2 9	..	..	..
860	..	0 6½	0 10½	1 2¼	1 6½	2 0	2 6	3 0	3 7	4 3	5 1	6 0	..
96	0 4	0 9½	1 3	1 7¾	..	..	..	..	..	..	..	..	..
53	0 4¾	1 0	1 7¼	2 2½	2 10¾	3 8	4 8	5 10½	..	..	..	..	..
152	0 4	0 8	1 0¼	1 4¼	1 8½	2 1	2 6¼	3 0¼	3 7¼	4 3¾	5 0	5 8¾	..
615	0 4½	0 11¼	1 6½	2 2	2 9¾	3 6½	4 3¼	5 0½	5 9¼	6 6½	..	..	..
38	0 7	1 9¼	2 11	3 11¼	4 11	..	..	..	..	..	..	..	..
63	0 4	0 11½	1 6½	2 1	2 7	3 1½	3 7½	4 2¼	4 9¼	5 3¼	..	..	..
884	0 7	1 7	2 6	3 4½	4 2½	4 11½	5 8	..	..	..	..	..	..
76	0 8½	1 8¼	2 8	3 8½	4 8½	5 10	..	..	..	..	..	..	..
154	0 8¾	1 3¾	1 11¼	2 8¼	3 8¾	..	..	..	..	..	..	..	..
64	..	1 11¼	3 2	4 3½	5 7	..	..	..	..	..	..	..	..
64	..	1 2	1 10½	2 6	3 1½	3 9½	4 5	5 0½	5 8	6 3¾	6 11	..	..
290	..	1 5½	2 4½	3 3	4 1	4 11	5 9	6 7	..	..	..	..	..
29	0 9½	1 9¾	2 10¼	3 11¼	..	..	..	..	..	..	..	..	..
69	0 5	0 10¾	1 4¼	1 11¼	2 5¾	3 0¼	3 7¼	4 1¾	4 7¼	..	..	..	..
370	0 10	2 0	2 11¼	3 9½	4 7¾	..	..	..	..	..	..	..	..
29	..	1 5½	2 7½	3 10	4 8½	..	..	..	..	..	..	..	..
81	..	0 6	1 0	1 4	1 8¼	2 1¼	2 6¼	2 11½	3 5	3 10	4 3	4 8	5 0¾
394	..	1 1½	1 11½	2 9½	3 7	4 4½	5 1	5 9	..	..	..	..	..
55	1 0¼	2 3¼	3 7¼	4 10½	..	..	..	..	..	..	..	..	..
63	0 5¾	0 11¾	1 6½	2 2½	3 1¾	4 1½	5 4¼	..	..	..	..	..	..
692	0 8	1 6	2 4	3 3	4 2	5 0	..	..	..	..	..	..	..
152	0 9½	1 8¾	2 7¾	3 6¼	4 5¾	5 4¼	..	..	..	..	..	..	..
67	..	1 6	2 8½	4 0¾	5 6¼	..	..	..	..	..	..	..	..
90	..	0 6¾	1 0¼	1 7	2 3	3 1½	4 1½	5 1½	..	..	..	..	..
408	..	0 5¾	1 0¼	1 8	2 4¼	3 4	4 5¼	5 8¼	..	..	..	..	..
68	..	0 7	1 2	1 9½	2 6	3 4½	4 4¾	5 6½	..	..	..	..	..
97	..	0 4¼	0 8¼	1 1¼	1 6¼	2 0	2 7¾	3 4¾	4 3¼	5 1	5 10½	..	..
546	..	0 4¼	0 8¾	1 2¼	1 8¼	2 2½	2 1[illegible]	3 8	4 7¼	5 7¼	..	..	..

Shorea robusta : rate of growth in girth, deduced

Province.	Forest division.	Approximate rainfall. inches.		Particulars.
Bengal.	Darjeeling (Tista valley range)	175	Divisional plots.	Fastest growth, unthinned, **Riang.** Slowest growth, unthinned, **Riang.** Mean of 5 unthinned plots.
	Jalpaiguri	150	Divisional plots.	Mean of 4 unthinned plots in **Lower Tondu and Muraghat.** Forest of good quality.
	Buxa	160	Divisional plots.	Mean of 8 unthinned plots, **4 in dry (high-level), 4 in** moist (low-level) forest: rate of **growth almost identical** in both types.
	Buxa and Jalpaiguri	. .	Plantations.	Good quality. Fair quality.
Assam.	Goalpara	155	Divisional plots.	Mean of 2 unthinned plots in high-**level forest.**
	Darrang	90	Divisional plots.	Mean of 2 unthinned plots in Gorumara and **Bahpara;** growth nearly same in both.
Bihar and Orissa.	Singhbhum and Kolhan	55-65	Divisional plots.	Mean of 4 unthinned plots, valley type. Mean of 4 unthinned plots, hill type.
	Palaman	50	Divisional plots.	Mean of 3 unthinned plots. **Kari and Kusumbhar.**
	Puri	55-60	Divisional plots.	Mean of 2 unthinned plots, **Kaduapara and Raju.**
	Angul	50-55	Divisional plots.	Fastest growth, unthinned, **Nimbochali.** Slowest growth, unthinned, **Rosonda.** Mean of 5 unthinned plots.
	Santal Parganas	50-60	Divisional plots.	Fastest growth, Kotangi, **ferruginous lateritic soil.** Slowest growth, Majdiha, **ferruginous lateritic soil.** Mean of 10 plots, all unthinned **except two.**
Central Provinces.	South Mandla	55	Divisional plots.	Fastest growth, Pakwar, very **open forest, fair quality.** Slowest growth, Kikra, somewhat **open crop, poor quality,** lateritic soil near trap. Mean of 6 unthinned plots.
	Balaghat	60	Divisional plots.	Fastest growth, No. 7*a*, Topla, moist, **free from frost.** Slowest growth, No. 2, Barkhera, much **damaged by frost.** Mean of 23 unthinned plots.

tom measurements in high forest sample plots.

No. of measurements.	20	40	60	80	100	120	140	160	180	200	220	240	260
	Age in years. Corresponding girth at breast height.												
	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in
63	0 9¼	1 8¼	2 7¾	3 9¼	5 0	6 1	..	..	..	..	..	..	..
29	0 7½	1 4¾	2 3	3 3¼	4 3	5 0¾	5 9¾	6 8¼	..	..	..	..	..
156	0 9¼	1 9	2 11¾	4 0¾	4 11¼	5 8	6 4¾	7 1¾	7 11½	..	..	..	..
262	0 11	1 11	3 1	4 5	6 0	7 7	..	..	..	..	..	..	..
289	1 0	2 0	3 0	4 0	5 0	6 0	..	..	..	..	..	..	..
..	2 6	5 0*	[6 3*	at 50 years of age]			..	..	..	..	..	..	..
..	2 0	4 0	6 0*	..	..	..	..	..	..	..	..	..	..
105	0 8	1 6	2 6	3 6	4 6	5 6	..	..	..	..	..	..	..
380	0 4	0 10½	1 5½	2 1	2 9½	3 7	4 5½	5 5½	..	..	..	..	..
132	0 8	1 5½	2 3¼	3 2	4 0	4 10	5 8½	6 6½	7 4½	..	..	..	..
163	0 10	1 8½	2 7	3 4	4 0½	4 8¾	5 5	6 1½	6 10	..	..	..	..
91	0 10½	2 0	3 3¾	5 0	..	..	..	..	..	..	..	..	..
133	0 10	1 9¾	2 11¾	4 2½	5 6¾	..	..	..	..	..	..	..	..
39	..	1 9	2 10	4 0¾	5 2¼	6 5½	..	..	..	..	..	..	..
71	..	1 4¼	2 1¼	2 10¼	3 8¾	4 7¾	5 6½	6 6¼	7 5¼	..	..	..	..
197	..	1 7¼	2 6½	3 7¾	4 10	6 0	7 0	7 11	..	..	..	..	..
46	1 2	2 4¾	3 5½	4 7	..	..	..	..	..	..	..	..	..
44	0 5¼	1 0	1 6½	2 0¾	2 7¼	3 1½	3 8	..	..	..	..	..	..
609	1 4¼	2 4¾	3 2¾	4 0½	4 10½	..	..	..	..	..	..	..	..
41	..	1 1	1 10	2 7½	3 4¾	4 2¼	5 0	5 9½	6 6	6 11¾	7 4¾	7 9½	..
72	..	0 7	0 11¼	1 4	1 8	2 0	2 3¾	2 7¾	2 11¼	3 3¾	3 7¼	4 0	4 3½
795	..	0 8¾	1 2½	1 7½	2 0½	2 5¾	2 11	3 4	3 9	4 2¼	4 7¼	5 1	5 6½
									[Girth of 6 ft. attained in 284 years.]				
18	..	0 8¾	1 3	1 9½	2 4½	3 1	3 11	4 9¼	..	..	..	..	..
33	..	0 1½	0 4	0 7	0 10	1 0¼	1 3½	1 6¼	1 9	2 0	2 3¼	2 6¾	2 10
1815	..	..	0 6½	0 9¼	1 1	1 5¼	1 9	2 1	2 5¾	2 10½	3 3¼	3 8	4 1
									[Girth of 6 ft. attained in 365 years.]				

* Estimated on basis of rate of growth for younger ages.

(b) *Form factors.* The following table of form factors, for all qualities combined, has been compiled from numerous measurements of typical trees in even-aged sample plots laid out by the Forest Research Institute :

Shorea robusta : form factors.

	Form factor.			Form factor.	
Height of tree.	Timber.	Total timber and small wood.	Height of tree.	Timber.	Total timber and small-wood.
ft.			ft.		
11–20	—	0·47	61–70	0·20	0·42
21–30	—	0·48	71–80	0·24	0·41
31–40	—	0·49	81–90	0·28	0·40
41–50	—	0·48	91–100	0·30	0·39
51–60	0·16	0·45	101–110	0·31	0·38

Note. (1) Form factor $= \frac{v}{sh}$, where v = solid volume in cubic feet, s = sectional area at breast-height, h = total height of tree.

(2) Timber excludes bark, and comprises everything down to a girth of 24 in. measured over bark ; small-wood includes bark, and comprises material 6 in. to 24 in. in girth.

Mr. J. V. Collier prepared the following statement of form factors of marketable timber in the bole, based on measurements of tall straight trees growing in the best quality of locality in the Haldwani forests :[1]

Girth	4 ft.	4½ ft.	5 ft.	5½ ft.	6 ft.
Timber form factor	0·60	0·59	0·56	0·57	0·56
Waste per cent. in conversion to scantlings .	19	20	19	20	19

(c) *Volume measurements.* Although numerous volume measurements of whole woods have been made in Research Institute sample plots, the compilation of results cannot be usefully attempted until further periodical remeasurements have been carried out, after which it should be possible to ascertain the rate of growth with some degree of accuracy, to define quality classes, and to make an estimate of intermediate yields. Current measurements in such crops have been published from time to time in the *Indian Forest Records*, but a compilation of general results has not yet been attempted.

Numerous figures giving the out-turn of coupes or the average out-turn of single trees are on record in different localities. These are of use locally, but for general comparative purposes they are for the most part of little value, since the out-turns have resulted mainly from very abnormal crops worked under selection or improvement fellings carried out under varying conditions, and in many cases the trees felled have been largely unsound or misshapen.

The following measurements made in 1916 and 1917 in sal plantations at Bareilly and Gorakhpur, on alluvial ground on the plains of northern India, are of interest :

Shorea robusta : measurements in plantations, Bareilly and Gorakhpur, United Provinces.

						Volume per acre.			
Locality.	Age.	Number of stems per acre.	Mean girth.		Mean height.	Timber 24 in. in girth and over.	Small-wood under 24 in. in girth.	Total.	Mean annual volume increment per acre.
	years.		ft.	in.	ft.	cub. ft.	cub. ft.	cub. ft.	cub. ft.
Bareilly	59	100	4	9	85	3,688	977	4,665	79·07
Gorakhpur	30	295	2	4	65	926	1,480	2,406	80·2

---

[1] Working Plan for the Haldwani Forest Division, United Provinces, 1914.

As regards the out-turn of single trees, two examples may be quoted in which the measurements were carefully made in respect of selected typical trees.

Mr. J. V. Collier in 1913–14 made some measurements of the out-turn of sal timber and scantlings from sound dominant trees in uniform close crops in the best quality of locality in the *bhabar* tract of the Haldwani forest division, United Provinces. The following statement gives a summary of the results:

Shorea robusta: average measurements and out-turn from well-grown sound dominant trees, Haldwani.

No. of trees measured.	Girth at 4½ ft.	Estimated age.	Total height of tree.	Length of timber bole.	Middle girth of timber bole over bark.		Middle girth of timber bole under bark.		Volume of timber bole without bark (πr^2).	Out-turn of scantlings.
	ft.	years.	ft.	ft.	ft.	in.	ft.	in.	cub. ft.	cub. ft.
48	6	134	99	59	4	5	4	0	75·7	46
49	5½	121	99	60	4	2	3	8	64·7	38·4
49	5	109	98	60	3	9	3	4	54·8	32 8
50	4½	97	95	56	3	5	3	1	41·8	23·3
50	4	86	93	55	3	1	2	9	33·9	17·9

The following are the results of measurements made by Mr. A. K. Glasson of a number of typical trees of different sizes in forest of good quality in Jalpaiguri, Bengal:

Shorea robusta: out-turn of typical trees, Jalpaiguri.

Girth.	Average volume in the round.	Girth.	Average volume in the round.
ft.	cub. ft.	ft.	cub. ft.
3	16	5	54
3½	23	5½	68
4	32	6	81
4½	42	over 6	90

As an example of a large out-turn from a single tree the case may be quoted of a tree felled in 1915 in the Tholkobad block, Singhbhum, which had a girth of 11 ft. 4 in. and a bole 60 ft. long. The out-turn of sleepers was as follows:

53 broad-gauge measuring	79·5	cub. ft.
34 metre-gauge measuring	39·4	..
14 narrow-gauge measuring	15·4	..
Total	134·3	..

(d) ***Bark allowance.*** Numerous measurements of bark thickness in the Dehra Dun forests gave the following averages:

Girth . . .	1–2 ft.	2–3 ft.	3–4 ft.	4–5 ft.	5–6 ft.
Bark thickness .	0·7 in.	0·9 in.	0·9 in.	1·1 in.	1·4 in.

Mr. J. V. Collier found the average percentage of bark in the total volume of the bole in the case of well-grown trees 4 to 6 ft. in girth in the Haldwani forests to be about 20.

2. *Coppice.* The height-growth of sal coppice is comparatively fast for the first two or three years, after which it becomes slower. Certain companion species—for example, *Grewia vestita*, *Lagerstroemia parviflora*, *Kydia calycina*, *Careya arborea*, *Cassia Fistula*, and *Terminalia tomentosa*—usually outgrow the sal in the earlier stages, but before long the latter overtakes all these species except *Terminalia tomentosa*, which keeps more or less level with it.

The following statement gives the results of measurements made in coppice coupes in different localities:

Shorea robusta: rate of growth of coppice.

Age	Ramgarh, Gorakhpur dist., U.P. Plains type. (C. M. McCrie, 1910.)			W. Lehra, Gorakhpur dist., U.P. Plains type. (Author, 1911.)			Dolmar, Naini Tal dist., outer Himalaya: hilly ground. (E. A. Smythies.)			Saitba, Kolhan forest division, Bihar and Orissa; poor hilly ground. (Author, 1916.)			Kulkaut sample plot, Santal Parganas.
	Mean girth.		Mean height.	Mean girth.		Mean height.	Mean girth.		Mean height.	Mean girth.		Mean height.	Mean height.
years.	ft.	in.	ft.	ft.	in.	ft.	ft.	in.	ft.	ft.	in.	ft.	
2	..		3	0	2·6	6	0	5	13	0	4	9	..
4	0	2	7	0	4·4	11	0	8·6	21	0	6·5	16	..
6	0	2·9	10·3	0	5·4	14	1	0	26	0	8·6	20	..
8	0	3·8	13	0	6·4	17	1	1·7	30	0	10·3	22·5	..
10	0	4·8	15·3	0	7·2	20	1	3·2	34	0	11·5	24·5	27
12	0	5·8	17·5	0	8	22·5	1	4·4	38	1	0·6	26·5	..
14	0	6·7	19·2	0	8·8	25	1	5·6	42	1	1·6	28·5	..
16	0	7·5	20·9	0	9·6	27	1	6·8	45	1	2·5	30	..
18	..		..	..		..	1	8	48	..		..	..
20	..		..	..		..	1	9·2	..	..		..	43
30	..			..		..	..		..	..		..	56

Out-turn figures for coppice recorded in coupe registers are not always to be relied on, since the figures are often vitiated by the inclusion of the out-turn of standards. The statement on the next page, compiled from measurements made by me in 1911 in coppice coupes in the West Lehra and Ramgarh forests, Gorakhpur, United Provinces, gives an idea of the volume yielded by coppice in coupes of different ages, (*a*) in specially selected fully stocked plots, and (*b*) as a general average. The measurements were made along straight lines ½ chain wide running through the coupes and embracing crops of various degrees of stocking.

2. **Shorea Tumbuggaia**, Roxb. Syn. *Vatica Tumbuggaia*, W. and A. Vern. *Karunthumbi*, *tambagai*, Tam.; *Thamba*, Tel.

A large tree with dark, thick, rough, longitudinally fissured bark. Trees up to 6 or 7 ft. in girth and 50 or 60 ft. in height are met with occasionally, but most of the large trees have been cut out: old stumps show that at one time trees up to 20 ft. in girth were sometimes to be found. This species does not attain so great a height as *S. Talura*. Wood very hard and durable, used for house-building, particularly for posts, rafters, and door and window frames. It lasts well under water, and is much used for well-linings.

DISTRIBUTION AND HABITAT. The tree occurs most plentifully, although its distribution is somewhat limited, in the Seshachellam and Veligonda hills in the Cuddapah and North Arcot districts of Madras: it is also found in limited quantity in the Kambakkan and Nagalapuram hills of the Chingleput

Shorea robusta : coppice measurements, Gorakhpur, United Provinces.

Locality.	Age.	Density: (*a*) Fully stocked patches: (*b*) General average.	Number of stems per acre (4 in. girth and over). Sal.	Other species.	Total.	Mean girth (sal 4 in. girth and over).	Mean height (sal 4 in. girth and over).	Solid volume per acre (material 6 in girth and over). Sal.	Other species.	Total.	Mean annual volume increment per acre (all species).
	years.					in.	ft.	cub. ft.	cub. ft.	cub. ft.	cub. ft.
W. Lehra coupe 10	8	(*a*)	1,690	262	1,952	..	..	235	23	258	32
		(*b*)	574	429	1,003	6·5	17	100	33	133	17
W. Lehra coupe 6	12	(*a*)	1,000	560	1,560	..	..	330	84	414	34
		(*b*)	561	809	1,370	8·2	23	185	121	306	25
Ramgarh coupe 6	12	(*a*)	1,480	1,880	3,330	..	..	283	139	422	35
		(*b*)	850	1,038	1,888	7·0	20	162	77	239	20
W. Lehra coupe 5	13	(*a*)	1,103	1,426	2,529	..	..	386	271	657	55
		(*b*)	476	916	1,392	8·5	22	167	174	341	26
W. Lehra coupe 4	14	(*a*)	901	1,868	2,769	..	..	261	299	560	40
		(*b*)	492	1,051	1,543	8·2	23	143	168	311	22
W. Lehra coupe 3	15	(*a*)	818	536	1,354	..	..	406	149	555	37
		(*b*)	681	580	1,261	9·4	27	338	161	499	33
Ramgarh coupe 3	15	(*a*)	1,545	1,600	3,145	..	..	295	152	447	30
		(*b*)	910	912	1,822	7·2	23	174	87	261	17

district. It is found chiefly in hilly country on well-drained ground, associated with *Pterocarpus santalinus*, *P. Marsupium*, *Anogeissus latifolia*, *Chloroxylon Swietenia*, *Terminalia tomentosa*, *T. Chebula*, *Buchanania latifolia*, *Eugenia Jambolana*, *E. alternifolia*, *Diospyros Melanoxylon*, *Dalbergia latifolia*, and other species, often with an undergrowth of *Phoenix humilis*. The tree is to some extent gregarious, forming patches of varying extent, chiefly on the upper slopes and crests of the hills and on plateaux, on well-drained ground with a soil usually consisting of red loam and gravelly sand. Fig. 58 shows a typical patch of forest. On dry ridges and plateaux the tree tends to become stunted, but on lower slopes and in valleys it reaches good dimensions. In its natural habitat the absolute maximum shade temperature is about 110° F., and the absolute minimum about 55° F.: the rainfall is about 30–35 in., of which more than half falls during the south-west monsoon from May to September, the greater portion of the remainder falling during the north-east monsoon from October to December.

FLOWERING AND FRUITING. The flowers appear in March–April, and the fruits ripen in June–July. Good seed-years are said to occur about once every two years. The seed occasionally starts germinating before falling from the tree; like that of other dipterocarps, it loses its fertility quickly, and if timely rain does not occur at the time the fruit falls or immediately after the seed fails to germinate.

SILVICULTURAL CHARACTERS. *Shorea Tumbuggaia* belongs to the xerophilous type of dipterocarps (see p. 32). Its silvicultural characters have not been studied in detail, but it apparently has good power of recovery from injury, having survived the effects of continued burning in the dry hilly tracts in which it is found. Natural reproduction in the Seshachellams is reported to be good in fire-protected areas.

3. **Shorea obtusa**, Wall. Vern. *Thitya*, Burm.

A large deciduous usually gregarious tree reaching a height of 80 ft. or more and a girth of 10 ft. and over; Mr. A. Rodger records one of 17 ft. in the Ruby Mines district. Bark thick, dark grey, brown inside, rough with deep longitudinal fissures. Wood very hard and durable, much used for building. Lac is occasionally produced on this tree.

DISTRIBUTION AND HABITAT. Except that it does not extend so far north, the distribution and habitat of this tree and its climatic requirements are practically the same as those of *Pentacme suavis*, with which it is very commonly associated in similar types of forest. It occurs as far north as the Ruby Mines district between 23° and 24° N. lat., and it is mentioned in the list of trees occurring in the Mawku and Ahlaw working circles in the Upper Chindwin district, 23° to 24° N. lat. (working plans by L. C. Davis and S. F. Hopwood).

LEAF-SHEDDING, FLOWERING, AND FRUITING. The leaves are shed in the early part of the hot season; the tree remains leafless during a portion of that season, or in moister localities the new leaves may appear very soon after the fall of the old ones. The inflorescences of yellowish fragrant flowers appear in March and the fruits ripen in May. The latter are five-winged, three of the wings being about 2 in. and the other two about 1½ in. long. The fruits are light and are blown to considerable distances: like that of

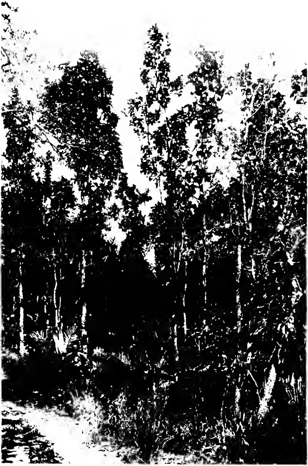

FIG. 58.—*Shorea Tumbuggaia* at 2,500 ft. elevation on the Seshachellam hills, South Cuddapah, Madras, with undergrowth of *Phoenix humilis*.

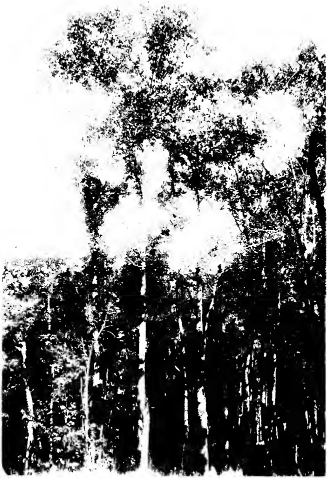

FIG. 59. *Shorea Talura* in Pikkilikona valley, Seshachellam hills, South Cuddapah, Madras.

other dipterocarps, the seed germinates soon after falling, and will not keep any time.

Silvicultural characters. *Shorea obtusa* belongs to the xerophilous type of dipterocarps (see p. 32), and its silvicultural characters are practically the same as those of *Pentacme suavis*. As in that species, the growing period is short, being confined to the hot season. The tree coppices well up to a moderate size, but is not known to produce root-suckers.

Natural reproduction. As with *Pentacme suavis*, reproduction is usually good, but the conditions governing it have not yet been studied in detail.

4. **Shorea Talura,** Roxb. Syn. *S. laccifera*, Heyne; *Vatica laccifera*, W. and A. Vern. *Talura, talari, punna-marom*, Tam.; *Jalari*, Tel.; *Jala*, Coorg; *Jhallanda*, Mysore; *Jhall mara*, Kan.

A large tree attaining a height of 80 ft. and a girth of 8–10 ft. Bark grey, somewhat smooth. Wood moderately hard, much used for house-building and for the large front posts of temples. Lac is sometimes produced on the tree.

Distribution and habitat. The southern Deccan districts of Madras, in Cuddapah, North Arcot and Anantapur, Mysore, Coorg, the Wynaad, Malabar, Coimbatore, and Madura, up to 3,000 ft. elevation. Travancore in Morrayur and Anjanad, rare (Rama Rao). This is a tree of the moist or evergreen forests in damp ravines and valleys, sides of streams, and lower slopes of hills, where it is associated with *Mangifera indica*, *Mimusops Elengi*, *M. hexandra*, *Eugenia Jambolana*, *Morinda tinctoria*, *Pterocarpus Marsupium*, *Dalbergia latifolia*, *Terminalia* spp., and other trees, and sometimes with *Shorea Tumbuggaia* and *Pterocarpus santalinus* in the southern Deccan hills. It is hardly a gregarious species, though it often occurs in patches of varying extent. Fig. 59 shows the type of forest in which it occurs. In its natural habitat the rainfall varies from 30 to 80 in. and possibly more, most of the rain falling between May and September and the greater portion of the rest from October to December: the absolute maximum shade temperature is about 110° F., and the absolute minimum about 50° F.

Flowering and fruiting. The white or pale pink flowers appear in February–March, and the fruits ripen in April–May.

Silvicultural characters. The silvicultural characters of this tree have not been studied in detail, but judging from its habitat it probably belongs to the hygrophilous type of dipterocarps (see p. 32). It is said to regenerate freely.

5. **Shorea assamica,** Dyer. Vern. *Makai*, Assam.

A very large tree with a long clean bole and rough brown bark. Wood light brown, handsome, open grained, much softer than that of *Shorea robusta*; it is of good quality, and if more plentiful would undoubtedly be in demand for various purposes.

Distribution and habitat. Upper Assam at the foot of the Naga hills in the Sibsagar and Lakhimpur districts in evergreen forests. Upper Burma in the Katha district, in moist valleys. Mr. Milroy[1] says it is reported to occur in evergreen forest in the Abor country near Pobamukh, associated with *Cedrela Toona*, *Terminalia myriocarpa*, *Castanopsis tribuloides*, *Amoora Wallichii*, *Cinnamomum Cecicodaphne*, *Morus laevigata*, *Michelia Champaca*, *Gmelina arborea*, and other species. In Assam it occurs sporadically mixed with many other kinds of large trees, or occasionally it is found growing more or less gregariously in patches of varying extent.

---

[1] Report on the Resources of the Abor Country, 1912.

In its natural habitat the absolute maximum shade temperature is about 100° to 102° F., the absolute minimum about 40° F., and the normal rainfall 80 to 160 in.

Leaf-shedding, flowering, and fruiting. Mr. Kanjilal informs me that in Assam the old leaves are shed from March onwards and the new leaves appear during the rains between June and August. It flowers in September, and the fruits ripen in January–February. In its region in Upper Assam there is much rain from February onwards.

Silvicultural characters. This species belongs to the hygrophilous type of dipterocarps (see p. 32). Its silviculture has not been studied in detail.

Rate of growth. Gamble's specimens showed 5 rings per inch of radius, giving a mean annual girth increment of 1·26 in., which is fairly fast.

5. PARASHOREA, Kurz.

Parashorea stellata, Kurz. Vern. *Kaunghmu*, Burm.

A very tall evergreen tree of the tropical forests of Martaban and Tenasserim and the eastern slopes of the Pegu Yoma. The flowers appear in March–April and the five-winged fruits ripen in April–May.

6. BALANOCARPUS, Bedd.

Balanocarpus utilis, Bedd. Black kongu. Vern. *Karin kongu*, Tinnevelly.

A large evergreen tree which has already been described to some extent under *Hopea parviflora*, with which it is often associated in that district. It has a smooth bark, which is much darker than that of *Hopea*. It flowers from the end of April to the beginning of June, and the fruit, which is wingless, ripens in the rains, falling under and around the trees, where regeneration springs up in quantity. This tree is more shade-bearing than *Hopea*. *Balanocarpus erosa*, Bedd., which is associated with *B. utilis*, has a larger and heavier wingless fruit.

7. VATERIA, Linn.

Vateria indica, Linn. Piny varnish or Indian copal tree.

A large handsome evergreen tree with a smooth grey bark and a cylindrical stem. Mr. H. Tireman records trees up to 17 ft. 3 in. in girth in the Coorg *ghat* forests. The tree yields a gum-resin of excellent quality. It has been extensively planted as an avenue tree in South Canara, Malabar, and Travancore.

Distribution and habitat. Western India from North Kanara to Travancore, up to 3,500 or 4,000 ft., chiefly in evergreen forests, but occasionally along rivers in deciduous forests. In Coorg it occurs both in the *ghat* forests and east of the *ghats* up to 3,500 ft. elevation, in the latter locality always in evergreen forest. Its most important companions are *Hardwickia pinnata*, *Hopea parviflora*, *Dipterocarpus indicus*, *Dysoxylum malabaricum*, *Artocarpus hirsuta*, *A. integrifolia*, *Calophyllum tomentosum*, *Dichopsis elliptica*, and *Mesua ferrea*. Enumerations carried out in 1914–15 by Mr. N. E. Shrigley in the evergreen forests of Coorg showed that this was the most plentiful of all the important species, there being on an average 73 trees 7½ ft. and over in girth per 100 acres. In the natural habitat of the tree the climate is humid: the absolute maximum shade temperature varies from 95° to 100° F., the absolute minimum from 55° to 65° F., and the normal rainfall from 80 to 200 in. or more.

Flowering and fruiting. The flowers appear from January to March, and the fruits ripen from May to July. The fruits are fleshy and wingless, 2–2·5 in. long, containing one large seed.

Silvicultural characters. The tree belongs to the hygrophilous type of dipterocarps (see p. 32). It is a pronounced shade-bearer.

Natural reproduction. The heavy seed falls close around the tree; it germinates readily, and natural reproduction is usually plentiful in the neighbourhood of seed-bearers, the seedlings standing a considerable amount of shade.

ORDER X. MALVACEAE

The trees of this order which are of chief forest importance in India are *Bombax malabaricum*, DC., the cotton tree, with a soft whitish wood used for packing-cases and in match-manufacture; *B. insigne*, Wall., with a similar but somewhat better wood; and *Kydia calycina*, Roxb., important more as a common Indian forest tree than as being of any great economic value. The order contains many plants of economic importance as producers of fibres, both from the bast and from the fruits; to the latter class belong the cotton plants (*Gossypium* spp.).

Genera 1. Bombax, Linn.; 2. Kydia, Roxb.; 3. Thespesia, Correa; 4. Eriodendron, DC.; 5. Adansonia, Linn.; 6. Durio, Linn.; 7. Cullenia, Wight.

1. BOMBAX, Linn.

Large deciduous trees with digitate glabrous leaves.

Species 1. *B. malabaricum*, DC.; 2. *B. insigne*, Wall.; 3. *B. scopulorum*, Dunn.

1. **Bombax malabaricum**, DC. Syn. *B. heptaphyllum*, Cav. Cotton tree. Vern. *Simal*, Hind.; *Sayar*, Mar.; *Burla*, *sauri*, Kan.; *Burgha*, Tel.: *Illavu*, Tam.; *Letpan*, Burm.

A very large deciduous tree with a straight cylindrical stem and horizontally spreading branches in whorls: large trees are nearly always buttressed at the base. Bark smooth, grey, 0·7–1 in. thick, that of young trees and branches covered with large conical prickles, that of older trees often with somewhat widely separated longitudinal cracks. The leaves are digitate, with five to seven leaflets.

The *simal* tree attains very large dimensions, a height of 130 ft. and a girth of 12 ft. above the buttresses being not uncommon. When grown under forest conditions it soon loses its lower branches and forms a clean bole sometimes 80–100 ft. in length to the lowest branch. Mr. Gamble[1] refers to a tree in Palamau which was 135 ft. high and 115 ft. in girth round the buttresses. A tree recorded from Travancore in 1909 had a girth round the buttresses at 5 ft. from ground-level of 42 ft., the girth above the buttresses, which averaged 20 ft. in height, being 15 ft. 4 in. Mr. J. G. F. Marshall[2] records a very large tree situated on shallow soil with a gravelly and free subsoil at an elevation of between 700 and 1,000 ft. on the summit of a small hill at the foot of the Coorg *ghats*, where the normal rainfall is 190 in. Its height was 195 ft., girth at 3 ft. from ground 102 ft., and at 30 ft. from ground 15 ft.; it had seven large buttresses which would have easily contained an elephant between any two of them. The wood is soft, light, whitish in colour and perishable, and soon becomes discoloured if not quickly sawn up. It is used for rough planking and for tea-boxes. Although not a first-class match wood, it has been used more than any other wood in India for the manufacture of a cheap grade of matches owing to its abundance and accessibility. The capsules furnish a silk-cotton used for stuffing pillows.

The economic value of the *simal* as a timber tree lies mainly in its rapid growth and volume-production, for although the actual value of the wood per cubic foot may be small, this tree may under favourable conditions yield returns higher than those yielded by trees with much more valuable timbers.

DISTRIBUTION AND HABITAT. Throughout India and Burma, except in the most arid tracts. It is most commonly found on flat alluvial ground near river-banks, where it is often gregarious (see Fig. 62). Here it grows fastest and reaches its best development on deep alluvial deposits containing a considerable proportion of sand. It is often found scattered in mixed usually deciduous forest and even in sal forest, and is a characteristic tree on grassy savannah lands, where it often becomes gregarious. It will grow on badly drained ground, but here the growth is comparatively slow and the development poor, the trees remaining stunted with tapering boles. In the Dehra Dun valley it is one of the commonest trees on patches of shallow soil overlying hard calcareous tufa; here it is stunted. Talbot says it grows in exposed situations on the hard trap of the Akrani (Satpuras) at 3,700 ft. altitude; the stems are often stout and short, with the branches shortened and curved upwards at the ends. It is often found in various unlooked-for situations; thus it penetrates for some distance into the Himalayan valleys and may be found scattered on the slopes of the hills, sometimes in very dry situations, up to about 4,000 ft. or even more. I have seen a tree at 5,000 ft. elevation above Mangoli in the Naini Tal hills, associated with *Quercus incana*. Its wide distribution is due to the fact that the cotton-covered seeds are carried by the wind to very considerable distances.

The *simal* occurs in regions showing a wide range of temperature and rainfall, but thrives best in a comparatively moist tropical climate. In its natural habitat, excluding places where it is found up to 3,000–4,000 ft. or more in the hills, the absolute maximum shade temperature varies from 95° to 120° F., the absolute minimum from 25° to 65° F., and the rainfall from 30 to 180 in. or more.

LEAF-SHEDDING, FLOWERING, AND FRUITING. In some cases, particularly in dry situations, the leaves may turn yellow and commence to fall in the beginning of December, the trees being leafless by the end of that month. Some trees, particularly in moist situations, may remain in full leaf till March. The new leaves appear in March or April. The large round dark brown buds become conspicuous in December. The showy scarlet flowers appear in January and February, and sometimes continue till March; the trees are usually leafless at the time of flowering, but if in leaf the flowers are as a rule not so numerous. The trees when in full flower present a striking blaze of colour; the fleshy petals are attacked by crows, minahs, and other birds, and when they fall to the ground they are eagerly devoured by deer. I have observed squirrels (*Sciurus maximus*) eating the flower-buds in quantities. Pollination is effected by bees, which visit the flowers in large numbers, as well as by birds, which seek the nectar or search for insects, and get their heads covered with pollen. Even martens (*Martes flavigula*) have been observed visiting the flowers in search of nectar.[1]

---

[1] Ind. Forester, vii (1881–2), p. 296.

[2] *Ibid.*, xiii (1887), p. 322.

The fruits develop very rapidly, sometimes reaching a length of 3 in. while there are still flowers on the tree; they ripen in April and May. The fruits are oblong woody five-valved capsules 4–6 in. long, which open usually while still on the tree, but sometimes after falling. The seeds, which are numerous, are surrounded by masses of white silky hairs, and are thus easily blown about by the wind. Strong dry winds are frequently prevalent at the time the fruits ripen, and where cotton trees are numerous the air is full of flecks of silk-cotton which are blown for miles, bearing the seeds with them. The seeds (Fig. 60, *a*) are 0·2–0·25 in. long, irregularly obovoid, dark brown, smooth, with a brittle testa: about 750 to 900 weigh 1 oz. Although the seeds are oily they retain their germinative power for some time if carefully stored. Tests carried out at Dehra Dun showed a fertility of 30 and 70 per cent. for seeds 1 year old, and 20 per cent. each for seeds 2 and 3 years old. Fresh seed always showed a higher percentage of fertility than old seed, and it is therefore advisable to use it whenever available. The seed, embedded in cotton, may be collected off the ground, or better still the capsules may be knocked off the tree when they are just about to open and placed in the sun, when they soon burst. A convenient method of separating the seed from the cotton is to place both in a large open basket. A round stick about 2 ft. long and ⅓ to ½ in. in diameter is prepared, and about 2 in. from one end of it two pointed cross sticks about 5 in. long are tied firmly to the long stick and at right angles to it and to each other. This end of the long stick is then pushed into the cotton and the stick is revolved rapidly in alternate directions by rubbing it between the palms of the hands: this causes the seeds to separate from the cotton and sink to the bottom of the basket.

Records for nine consecutive years in the Bengal Duars show that in that tract a good seeding may be expected annually. This is not the case in the United Provinces, where records for seven years indicate that an abundant crop of seed may be expected about once in two years.

GERMINATION (Fig. 60, *b–f*). Epigeous. The testa splits and the radicle emerges from the narrow end of the seed and descends. The hypocotyl elongates, arching at first, and in straightening carries above ground the cotyledons, which are much crumpled in the seed but soon expand. The testa is either left in the ground or carried up over the cotyledons, falling with their expansion.

---

[1] G. B. F. Muir in Journ. Bomb. Nat. Hist. Soc., xxiv (1916), p. 589.

THE SEEDLING (Fig. 60).

Roots: primary root long, at first thin, afterwards thickening greatly and becoming fleshy, terete, tapering upwards and downwards from the fleshy part, at first white, afterwards yellow or light brown: lateral roots few or moderately numerous, chiefly on upper part of main root. *Hypocotyl* distinct from root, 1·2–2·4 in. long, at first thicker afterwards thinner than taproot, terete, tapering slightly upwards, white and delicate at first, afterwards becoming green and tougher, glabrous or minutely pubescent. *Cotyledons*: petiole 0·1–0·2 in. long, channelled above, glabrous: lamina 1–1·2 in. by 1 in., foliaceous, cordate, acute, entire, green, glabrous, palmately 5-veined from base, secondary veins reticulate. *Stem* erect, terete, at first tough, later woody, green becoming yellowish brown, glabrous; internodes 0·2–0·5 in. long. *Leaves* alternate, first one or two simple, followed by a few (up to five) 3-foliate leaves, followed by several 5-foliate digitate leaves, sometimes with one or more 4-foliate leaves intervening: in second season leaves 5- to 7-foliate. Stipules 0·2 in. long, linear lanceolate. Simple leaves with petiole 0·5–1·2 in., terete or slightly flattened above, glabrous, lamina 1·5–2·7 in. by 0·9–1·2 in., ovate or cordate, acuminate, glabrous, venation reticulate. Trifoliate leaves with common petiole 3–5 in. long, leaflets sessile or sub-sessile, glabrous, lateral pair 2–4·5 in. by 0·8–1·8 in., unequally ovate lanceolate, acuminate, terminal leaflet 3–7 in. by 1–2 in., elliptical ovate or obovate lanceolate, acuminate.

The growth of the seedling during the first season is slower than it is subsequently. At Dehra Dun seedlings attained a height of 3–6 in. by the end of the first season, while those which were regularly weeded and watered grew rapidly during the second season, some reaching a height of 5½ ft. by the end of the season: in more tropical climates the growth is even faster. On stiff soil and on other unfavourable ground the seedlings remain small for two or three years or more, growing only a few inches a year. In dry localities they may die back annually for a few years before establishing themselves and commencing upward growth. The seedlings are tender to frost, and this dying back may also take place in frosty localities, the young plants being killed back to ground-level in the winter and producing new and stronger shoots next spring. Prickles, which are at first small, commence to be produced on the stems of vigorous seedlings in the second season: in more backward seedlings they do not appear until later. In northern India new growth starts in April or May and continues till October; the growth is greatest from June to August. A feature of the seedling is the long thick fleshy taproot, which in vigorous plants may reach a length of 1 ft. or more in two months and 1½ ft. or more by the end of the first season. Seedlings are subject to the attacks of various animals; hares nibble the stem, rats gnaw the taproot, and pigs and porcupines grub up the roots.

SILVICULTURAL CHARACTERS. The cotton tree is a strong light-demander. It resists slight frosts, but is affected by severe frosts in northern India. In famine years it has been found to be unaffected by drought. Growing as it does in savannah tracts it is subject to severe burning: in the seedling and sapling stage it is repeatedly burnt back, but has good power of recovery from the base, and once it is established its thick bark enables it to resist damage by fire better than most species. It benefits greatly, however, from fire-protection. It coppices in its early years but not later, and is not known to produce root-suckers. It suffers from grazing, and in its young stages benefits much from the protection of thorny bushes.

Natural reproduction. The spread of the seed by wind and the consequent wide distribution of the tree have been noted. Natural regeneration establishes itself freely on new alluvial flats, savannahs, and other open spaces. In northern India it is one of the first trees to make its appearance on alluvial ground in the stage subsequent to that in which the land is occupied by *Dalbergia Sissoo* and *Acacia Catechu*. In heavily grazed areas the saplings establish themselves freely under the protection of dense clumps of *Zizyphus Jujuba*, *Z. Xylopyrus*, and other armed shrubs, or in tussocks of coarse grass, where they are out of reach of cattle. Similarly it is often seen making its way through hedgerows and thickets of *Acacia Catechu*. In the Central Provinces *Zizyphus Oenoplia* furnishes the same useful protection, and *Bombax* regeneration sometimes makes its way in quantity through thickets of this otherwise noxious climber. It is owing to this early protection and to the capacity of the seedlings for pushing their way through clumps of bushes that the *simal* frequently becomes gregarious even on land subject to heavy grazing. Experiments have shown that dense weed-growth greatly hampers the development of the seedlings, and it is therefore probable that several years are occupied in their pushing their way through shrubby growth if this is at all dense. Fig. 61 shows typically the manner in which the saplings establish themselves in thickets of shrubs in grazed areas, while Fig. 62 shows a later stage of growth on an adjacent area of the same type. On abandoned cultivation saplings often spring up in quantity and grow rapidly. The beneficial effects of fire-protection on the natural reproduction of this tree may be observed in any of the fire-protected tracts in which it grows, for although once established it has considerable power of resistance to fire, numbers of seedlings are destroyed for every one which becomes established: in many places, indeed, the introduction of fire-protection is followed by a plentiful crop of natural reproduction wherever there is sufficient light.

Artificial reproduction. Numerous experiments in the artificial reproduction of the *simal* have been carried out within recent years at Dehra Dun and on a larger scale in Assam, the United Provinces, and elsewhere. The most satisfactory method of raising plantations has not yet been determined, but the results detailed below indicate that so far the greatest success has been attained, in the order given, by

(1) irrigated line sowings, which, however, will probably prove too expensive in practice;
(2) sowings in conjunction with field crops; and
(3) unirrigated weeded line sowings.

Transplanting of nursery-raised plants has not hitherto proved much of a success.

The financial success of plantations of soft-wooded species of comparatively small value must depend largely on a rapid rate of growth, or, in other words, on the careful selection of a site, intensive weeding in the early stages, and regular thinnings to promote development. Above all, stiff clay or shallow rocky soil should be avoided, for not only will the growth and development be poor, but the seedlings will be liable to die back for some years before establishing themselves, owing on the one hand to bad drainage and on the other to drought: the same dying back occurs in frosty localities, which should also be avoided. On water-logged ground failure is almost certain to result owing to the tendency of the thick fleshy taproot to decay in such localities. Deep porous alluvium with a considerable proportion of sand will produce the best growth. A contingency by no means negligible is the damage done by animals, especially pigs, which root up the seedlings, and rats, which gnaw through the thick fleshy roots.

Spacing. The best spacing in plantations has not yet been determined. Close planting is unnecessary, owing to the rapid growth of the trees and the space required by them for development. In Assam spacings of 20 ft. by 20 ft. and 24 ft. by 12 ft. have been tried, but this is perhaps somewhat wide, hardly allowing sufficient margin for casualties and for the removal of misshapen stems. Ordinarily a spacing of about 12 ft. by 12 ft. should meet requirements. In line sowings a distance of about 15 to 18 ft. between lines will probably be found suitable, and 1 oz. of seed will be found sufficient for about 250 ft. of line.

Rotation and yield. The rotation, depending on the rate of growth, must vary greatly with the locality. Under optimum conditions, judging from the rate of growth of natural trees, a girth of 6 ft. may be expected to be reached in twenty years; it would, however, be quite unsafe to count on such a short rotation in actual practice, even in very favourable localities, since time must be allowed for the establishment of the seedlings as well as for unforeseen contingencies. Even in localities of the best quality it would be unsafe to reckon on a rotation of less than twenty-five years to produce an average girth of 6 ft., while under ordinary favourable conditions a rotation of thirty years might be reasonably estimated. Where the seedlings tend to die back in early youth or to establish themselves slowly, a suitable period would have to be added to the actual growing rotation. On unsuitable localities, such as badly drained areas, or where there is risk of damage by frost, drought, fire, grazing, or other injuries, an estimate of the rotation could not be anything but conjectural, and indeed it may be accepted as fairly certain that *simal* plantations cannot be expected to pay in such localities.

The actual yield per acre will vary with the quality of the locality, but judging from measurements of natural trees it is estimated that a well-tended plantation grown on a rotation sufficient to produce trees of 6 ft. girth in a favourable locality should yield about 4,400 cub. ft. of utilizable timber per acre (excluding bark and waste wood): this allows for 3,500 cub. ft. in the final yield (trees 6 ft. in girth) and 900 cub. ft. of intermediate yield (trees $4\frac{1}{2}$–6 ft. in girth cut out in thinnings). These figures are not based on measurements in actual plantations, which are not yet available, and should therefore be regarded as only provisional.

Results of experiments. The various experiments hitherto undertaken in the artificial propagation of *simal*, with the results attained, are as follows:

1. *Early tending.* The question of early tending may be considered first, as it affects all forms of artificial reproduction. Experiments at Dehra Dun

Fig. 61.—*Bombax malabaricum*: young trees (leafless) establishing themselves under the protection of a dense growth of *Zizyphus Jujuba* on heavily grazed land, Dehra Dun, United Provinces.

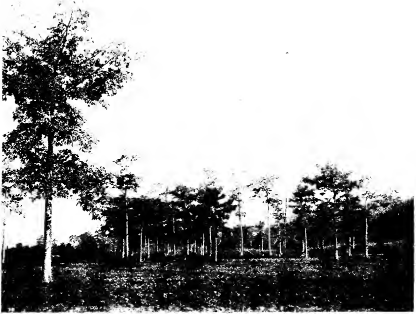

FIG. 62. *Bombax malabaricum*, trees growing gregariously on alluvial land, Dehra Dun, United Provinces.

have demonstrated the necessity for weeding thoroughly round the young plants during the first two years and keeping the soil loosened where it is liable to cake; thereafter it is necessary to keep the plants free from all overhead cover until they are thoroughly established. In line sowings such weedings were found to have remarkable results: thus, the height-growth in weeded lines during the first two years was twice and four times that in unweeded lines in irrigated and unirrigated sowings respectively, while the vigour of the weeded plants was far greater than that of the unweeded plants, the latter being thin and lanky and often unable to stand erect without support, while a large proportion were killed out by suppression. Another important result of weeding is the fact that in the weeded lines the plants are less liable to damage by frost, no doubt owing not only to the freer circulation of air, but also to the greater vigour of the plants. Weeding should commence early in the first rains, and should be continued at frequent intervals as required. The same applies to the loosening of the soil, which should be continued during the following winter and hot season: this operation can be done expeditiously with a hand plough or a small weeding fork. A second measure of importance in line sowings is the thinning out of plants where they are congested, the more vigorous individuals being left and the weaker ones removed: opportunity should be taken during this operation to utilize the best of the surplus plants to fill up gaps, otherwise the most expeditious method of thinning out the seedlings is to drive a *kurpa* or large knife down through the taproot so as to sever it, and pull the plant up. This thinning out of seedlings should commence not later than the early part of the first cold season, and should be repeated about once a year for the first two or three years, leading on to regular thinnings at longer intervals.

2. *Propagation by cuttings.* Experiments in propagation by cuttings have not justified the employment of this method in practice. In Assam, cuttings about 6 ft. long and 2 in. in diameter were found to strike well, but the subsequent percentage of mortality was high. At Dehra Dun smaller cuttings raised in the nursery were also found to strike well, but a very large percentage died subsequently: they were found to do best if put down early in the rains in a slanting position, only a few inches (including at least one bud pointing upwards) being left above ground in order to produce a straight new shoot from near ground-level.

3. *Transplanting nursery-raised seedlings.* Experiments at Dehra Dun have shown that although with care nursery-raised seedlings can be transplanted without much difficulty, they are apt to receive a check to their growth in the process, and the results have been decidedly inferior to those attained by weeded line sowings *in situ*. In the nursery the seed should be sown in drills before or at the commencement of the rains in well-raised beds on light soil containing a good proportion of sand, and should be lightly covered with earth. If the plants are to be transplanted in the first year, a distance of about 8 in. between drills will suffice, but if they are to be kept in the nursery till the second year, the distance should be not less than 1 ft. The beds should be regularly watered in dry weather and weeded, the soil being kept loosened. The seedlings ordinarily appear about one to three weeks after sowing, and are ready for planting out one to two months later; even then the taproot is

often 8 to 12 in. long, but with reasonable care there is no difficulty in transplanting into pits. The plants may be kept in the nursery till the second rains, by which time they will have reached a considerable size and will require to be 'stumped' before transplanting. For this purpose the stem should be pruned down to about 3 in. from ground-level, and the taproot pruned down to about 9 in. in length; this treatment has not been found to do any material harm to the seedlings, and is necessary owing to the large size of the taproot. Experience in Assam has shown that plants which have been transplanted three or four times in the nursery, and are then removed to the plantation, stand planting out best, but make little progress afterwards, whereas those which are removed straight from the seed-beds, although they are more susceptible to the shock of planting out and produce more casualties, show quicker subsequent growth. The latter condition is certainly preferable to the former, and the increased mortality can be counteracted by closer planting. Further experiments are desirable in the transplanting of stumped plants in the second or even the third rains.

4. *Irrigated line sowings.* Experiments with irrigated line sowings at Dehra Dun have proved remarkably successful, the plants reaching a maximum height of nearly 10 ft. in $2\frac{1}{2}$ years and showing vigorous development. It is doubtful, however, if the expense of irrigation could be justified on a large scale by the corresponding increase in growth, particularly as the results attained by experimental weeded unirrigated line sowings have not been greatly inferior to those attained by irrigated sowings: on the other hand, the cost could be recouped to some extent by growing field crops between the lines in the early years of the plantation. In carrying out irrigated line sowings the seed is lightly dibbled in along the base of the ridge of earth thrown up from irrigation channels, a flat space of a few inches being left between channel and ridge. The channels should be 1 ft. deep with an average width of 1 ft., and should be cleared of silt periodically. The importance of frequent weeding and of thinning out congested seedlings has already been alluded to. Fig. 63 shows the result of irrigated line sowings at Dehra Dun.

5. *Unirrigated line sowings.* This form of establishing *simal* plantations is one which is applicable mainly to open tracts not covered with tree-growth, since it is doubtful if it would pay to clear and burn forest land for the establishment of *simal* plantations without the aid of field crops. This system has been tried experimentally at Dehra Dun with considerable success. Two methods of preparing the lines were tried, one in which the ground was dug up with a hoe to a width of 1 ft. and levelled, and the other in which a double furrow was made with a plough run once up and down the line. There was nothing to choose between the respective results, while the ploughing was cheaper than the hoeing; on stiffer soil, however, it would no doubt be found advantageous to break up the clods on the ploughed line. Subsequent weeding along the lines was, as already stated, found to be essential to success, while loosening of the soil in the first year or two had a marked effect on the development of the plants. After $2\frac{1}{2}$ years the maximum height in the weeded lines was nearly 10 ft., though neither the average height nor the general development of the plants was quite equal to that of the irrigated line sowings.

Experimental line sowings in the large grassy blanks (*phantas* and *chandars*) of the Kheri district, Oudh, have been in progress for some years, with varying results. Numerous failures have occurred, some owing to pigs and rats, some to frost, some perhaps to the stiffness of the soil or want of drainage in places, and some to damage by fire. In the earlier years the plants also suffered from the attacks of insects, which damaged the leading shoots. The most fruitful cause of failure in the earlier experiments, however, was probably the fact that weeding was not carried out, for the success has been greater since regular weeding was instituted. These areas are covered with a heavy growth of high savannah grass, and unless the lines are kept clear a considerable proportion of the seedlings are liable to be killed by suppression.

6. *Plantations raised with unirrigated field crops.* In experiments at Dehra Dun, line sowings in combination with field crops have given greater success than any other form of artificial reproduction without the aid of irrigation. The field crop employed was the lesser millet or *mandwa* (*Eleusine coracana*). and the ground being fertile cleared forest land it formed a dense crop 3½ ft. high. The crop was sown towards the end of May and reaped in October, and the lines of *simal* were sown immediately after the sowing of the crop. Two separate methods were tried, one in which the field crop was sown evenly over the whole area, the *simal* seedlings coming up under its shade, and the other in which the field crop was sown in the spaces intervening between the lines, a clear strip 1½ to 2 ft. wide being left along the lines. The latter system was much more successful than the former, and is the one recommended for adoption : the cultivator keeps the lines weeded and the soil loosened during the first rains, and the light admitted to the clear strip causes the plants to develop satisfactorily. Where the crop was sown evenly over the whole area without leaving clear strips for the *simal*, the latter became weak and lanky and dropped their leaves prematurely with the sudden exposure when the crops were reaped.

In Assam, *simal* plantations have recently been formed in combination with rice cultivation in *jhums*, that is, temporary forest clearings in which the felled material is thoroughly burnt prior to the sowing of the crops. The results have been very encouraging, and in some cases the plantations have cost nothing to form, the *simal* seed having been sown and the young plants tended free by the cultivators in return for permission to cut *jhums* in reserved forests. Among the earlier experiments may be mentioned a plantation of 80 acres at Kerwa in the Lakhimpur district, in which seed was sown in 1914. Two years later the plantation was reported to be practically fully stocked, there being 11,036 young trees averaging 12 ft. in height. In the North-East Frontier district there were about 450 acres under *simal* in 1917.

The system adopted has been described as follows by Babu R. N. De :[1]

> 'Early in June or July, varying according to the time when the Simul seed ripens, it is collected by the Forest Department and distributed to the villagers, who, at this time of the year, sow rice in their newly cleared "jhums". Before the rice is sown they have to put up stakes in their jhums at 26′ × 26′ and then the rice is sown with the Simul seed, the latter at each stake. Sometimes the rice is sown before the Simul. Five to ten seeds are put at each stake ; this is done to be perfectly sure that there will be no failure. In some cases the staking is done under the supervision of Forest Officers, but in the

---

[1] Ind. Forester, xliv (1918), p. 517.

North-East Frontier District the Miris do it themselves under the instruction of Forest Officers, as the Forest staff is insufficient to do the staking in a number of villages, scattered over a considerable area. If the seeds are good, they germinate freely within six or seven days. Though Simul does not grow so quickly as the rice plant, it is not at all injured by the latter. If, at any stake, no Simul seed has germinated, seedlings are transplanted from those stakes where there are more than one.

'As the transplantation is carried on, only the best seedling is kept at each stake and the rest are transplanted if necessary, or removed. After the rice has been cut, the area is cleared and mustard, rye, potato, etc. are grown in the jhums. By this time the Simul plants are 1′–2′ high. Next year in the rains, the rice is sown again after clearing the area of weeds, and this rice is weeded once or twice during the rains. In the rains the Simul plants grow very vigorously, some of them attaining 6′ in height. Having received such careful tending from the very start, no amount of weeds and fast growing shrubs can hinder their growth and by the winter of the second year most of the plants are 8′ and over in height; Mr. Jacob, Deputy Conservator of Forests, has measured seedlings which have attained 15′ in height in their second cold weather. The Miris usually abandon their jhums at the end of the second year after growing mustard, etc. The plants now need no looking after and can fend for themselves, but if the land is cultivated for the third year, the plants do still better. The Miris can grow crops underneath Simul without difficulty, as it has a very light crown.

'As from its habit Simul does not grow any more branchy when isolated, and as the height growth of this tree is not appreciably stimulated by growing the plants closer together, thinning and cleaning operations are unnecessary. It was found that when planted 12′ × 24′, branches were interlacing by the third year; this is why plants are put in 26′ × 26′. Much knowledge has yet to be gained as to the best distance at which plants should be spaced.'

SILVICULTURAL TREATMENT. With protection from fire and from excessive grazing, the tree springs up in abundance on suitable ground, but if permanent supplies of timber are required in regular quantities at cheap rates it is doubtful if any system would be as suitable as that of clear felling with artificial regeneration on a definite rotation. Experience has shown that where the demand for the wood is keen, as in certain districts in Assam, where it is used for tea-boxes, the supplies of natural *simal* may easily become exhausted in spite of the readiness with which it regenerates.

RATE OF GROWTH. Under favourable conditions the rate of growth of *simal* is very fast, a growth of two rings per inch of radius, representing a mean annual girth increment of over 3 in., being by no means unusual. In less favourable localities the growth is considerably slower. Mr. S. E. Peal[1] states that a tree felled in Assam in 1883 had sixteen annual rings on a radius of 21 in., the rings varying from ½ in. to 2¼ in. in width. This represents a mean annual girth increment of 8·2 in., at which rate a tree would reach a girth of 6 ft., excluding bark, in about nine years; this would appear almost incredible were it not that the tree grew on the site of former coolie lines which the writer states were known to him. In estimating the age of *simal* in localities where the seedlings die back owing to frost or other causes, the addition of some years for the time required for the establishment of the seedling is a necessary precaution. The annual rings in *simal* are clearly visible, and the rate of growth can thus be readily ascertained from ring-countings on stumps.

---

[1] Ind. Forester, ix (1883), p. 539.

Mr. E. Marsden ascertained from an examination of six trees at Dehra Dun that each internode represented a year's growth; if this holds good generally, then it should be possible to estimate the age of standing trees fairly accurately by counting the number of internodes between whorls of branches.

2. **Bombax insigne,** Wall., including *B. cambodiense*, Pierre, and *B. anceps*, Pierre.

The sub-species and varieties of this tree have not yet been fully determined. Gage[1] describes the following:

I. Sub-sp. *genuina*, Prain.

(*a*) Var. *typica*. A large tree reaching a height of 100 ft. and a girth of 20 ft. Bark more or less covered with conical prickles. Leaves digitate with 5–12 leaflets. Flowers with red petals about 5½ in. long. Capsules 6–8 in. long by 1·6 in. in diameter.

Loc. Chittagong, Arakan, Burma (Bhamo, Pegu and Arakan Yoma, Tenasserim, N. Shan States). Vern. *Didu-pyu*, Tenasserim; *Shin*, Tavoy; *Sit-pan bewip*, N. Shan States; *Didôk*, *kôkhè*, Pyinmana.

(*b*) Var. *Wightii*, Prain. A large tree with more or less prickly bark. Leaflets 5–6 or more. Petals red, about 3½ in. long. Capsules about 5–7 in. long by 2 in. in diameter.

Loc. Burma (Shwegyin): Indian Peninsula on the W. Ghats. Vern. *Didu*, Burm.

II. Sub-sp. *anceps*, Prain.

(*a*) Var. *vera*. Syn. *B. anceps*, Pierre. A lofty tree reaching a height of 100 ft. and a girth of at least 16 ft. Bark greyish, more or less prickly when young. Leaflets 5–7. Petals red or white. Capsule woody, dark brown, 3¼–4 in. long with five very prominent rounded ridges.

Loc. Burma (Pegu and Arakan Yoma, Upper Burma, N. Shan States, Salween). Vern. *Didu-pyu*, *didôk*, Burm.; *Kowa*, Karen.

(*b*) Var. *cambodiensis*. Syn. *B. cambodiense*, Pierre.

A tree reaching a height of about 80 ft. Bark grey, covered with conical spines. Leaflets usually seven.

Loc. Upper Burma, Cambodia.

Of other varieties distinguished by Prain[2] may be mentioned var. *andamanica*, so far found only in the Andaman Islands, and differing from the normal type in having narrow leaflets.

If any silvicultural distinctions exist among the different sub-species or varieties, they have not yet been studied, and the species may be considered as a whole. Generally speaking this is a large deciduous tree with grey bark, which in youth at least is covered with conical prickles. In dimensions it probably equals *B. malabaricum*, which it also resembles somewhat in general appearance, the chief superficial distinction being that *B. insigne* has larger flowers and usually more numerous leaflets. In Burma its usual name is *didu*, sometimes *didôk* (or *kôkhè* in Upper Burma for var. *cambodiensis*). The wood is superior to that of *B. malabaricum*, and, as in the case of that species, the capsules furnish a silk-cotton.

DISTRIBUTION AND HABITAT. The natural home of this tree is in Burma, the Andamans, Chittagong, the Malay Peninsula, and the **Western Ghats** from North Kanara southwards. In Burma it is most commonly found in the upper mixed deciduous forests associated with teak and its usual companions on well-drained often hilly ground ; here it reaches large dimensions. In Burma it is not so gregarious as *B. malabaricum*, and is typical rather of hilly or undulating ground than of alluvial flats. Talbot says that in North Kanara it is gregarious from the coast upwards to the crest of the *ghats*, that it is also found in the Konkan and Deccan districts, and often occurs on laterite. In the Andamans it is common in deciduous forests on well-drained hilly ground, usually on micaceous sandstone, associated with *Pterocarpus dalbergioides*, *Lagerstroemia hypoleuca*, *Sterculia alata*, *S. villosa*, *Artocarpus Chaplasha*, *Albizzia Lebbek*, and other deciduous trees. It also extends along with some of its usual companions into the evergreen or semi-evergreen forest on hill slopes, associated with *Dipterocarpus* spp. and other trees characteristic of these types.

---

[1] Ind. Forester, xxxiii (1907), p. 115.

[2] Journ. Asiat. Soc. Beng., lxii, 1893.

Bombax insigne is essentially a tree of tropical regions, where the absolute maximum shade temperature varies from 96° to 110° F., the absolute minimum from 42° to 60° F., and the rainfall from 40 to 150 in. or more.

LEAF-SHEDDING, FLOWERING, AND FRUITING. In Burma the tree usually sheds its leaves early in December, and remains leafless till May. The flowers, usually red, sometimes white, appear at the end of December and in January, the capsules ripening in April. In the Andamans the capsules commence to ripen in March. The seed, enveloped in silky cotton, is dispersed by wind as in the case of *B. malabaricum*. Seeds received from the Andamans were 0·25 in. by 0·2 in., obovoid, dark brown, smooth, with a fairly hard but brittle testa : in two separate samples, 330 and 570 seeds respectively weighed 1 oz. The seeds are oily. Gage [1] describes seeds of sub-sp. *genuina* var. *Wightii* as pyriform compressed 8 mm. by 5 mm. (i.e. 0·3 in. by 0·2 in.), and those of sub-sp. *anceps* var. *vera* as ovoid compressed 8 mm. by 5 mm. The seed keeps indifferently ; a sample kept for one year showed a fertility of only 5 per cent.

SILVICULTURAL CHARACTERS. The silvicultural characters of this tree have not yet been studied.

3. **Bombax scopulorum**, Dunn.

This is a tree of the forests of Travancore described by Bourdillon, under the name of *B. insigne*, as a 'small tree having the appearance of the cotton tree but never attaining its size'.

2. KYDIA, Roxb.

Kydia calycina, Roxb. Syn. *K. fraterna*, Roxb. ; *K. Roxburghiana*, Wight. Vern. *Pula*, *puli*, *patha*, Hind. ; *Kakahi*, Oudh ; *Barranga*, C. P. ; *Kopasia*, Uriya ; *Warang*, *iliya*, Mar. ; *Bellaka*, *bendi*, Kan. ; *Potri*, *pandiki*, Tel. ; *Dwabôk*, *myethlwa*, Burm.

A moderate-sized deciduous tree with grey bark exfoliating in irregular flakes or long strips. A tree with soft white wood, of little value commercially, but important owing to its abundance in certain types of forest.

DISTRIBUTION AND HABITAT. Common throughout India and Burma, chiefly in mixed deciduous forests ; not in arid regions. In the sub-Himalayan tract abundant in many of the mixed forests, and in sal forest; in Burma frequent in the lower mixed deciduous forests of the plains.

---

[1] *loc. cit.*

LEAF-SHEDDING, FLOWERING, AND FRUITING (observations made in north India). The leaves commence to fall at the end of November, and the tree is leafless from January or early February to late April. The tree flowers and fruits at an early age. The flowers appear in September–October, and the masses of greenish white or pale lilac blossoms make the trees a conspicuous sight at this season. By the middle of November the fruits begin to form; they ripen from early January to late March, and by April most of them have fallen. The fruit is a three-valved capsule subtended by the dry persistent calyx: the fruiting panicles, which are brittle, fall off whole or in pieces or are blown off by the wind. The seeds (Fig. 65, *a*) are greyish brown, 0·1 in. diam., reniform, furrowed with fine striations, with a fairly hard testa; about 900 weigh 1 oz. The seeds are best obtained by collecting the dry fruiting panicles about February, rubbing them in a cloth or bag, and separating the seeds by winnowing. Tests carried out with different samples, of seed have shown that the percentage of fertility is usually low.

GERMINATION (Fig. 65, *b–d*). Epigeous. The testa splits and the radicle emerges and descends. The hypocotyl elongates, arching somewhat, and in straightening raises above ground the cotyledons enclosed in the testa, which falls to the ground with the expansion of the cotyledons.

THE SEEDLING (Fig. 65).

Roots: primary root in the first year moderately long and thick, terete, tapering, in the second year in vigorous plants long (sometimes over 2 ft.), thick and fleshy: lateral roots moderate in number, fibrous, distributed down the main root. *Hypocotyl* distinct from the root, 0·3–0·5 in. long, terete, fusiform or tapering upwards, white turning green, minutely pubescent. *Cotyledons*: petiole 0·25–0·3 in. long, pubescent: lamina 0·3–0·45 in. by 0·3–0·5 in., foliaceous, orbicular, base truncate or slightly cordate, entire, sparsely pubescent. *Stem* erect, terete, pubescent; internodes 0·4–1·2 in. *Leaves* simple, alternate, petiolate, earlier leaves small, the size rapidly increasing. Stipules up to 0·1 in. long, linear. Petiole 0·4–1·5 in. long, pubescent. Lamina 0·4–2·5 in. by 0·4–2·5 in., orbicular cordate, apex acute or rounded, crenate or crenate dentate, dark green when young, becoming paler green, pubescent, palmately 5-veined.

The growth of the seedling is slow during the first season, but plants regularly weeded and watered at Dehra Dun attained a height of nearly 4 ft. by the end of the second season. On stiff soil or in heavy weed-growth the development is slow, seedlings under these conditions having attained a height of 1 in. and 9 in. by the end of the first and second seasons respectively. In northern India the seedlings are leafless during February and March, new growth commencing towards the end of March or in April.

SILVICULTURAL CHARACTERS. Although it stands moderate shade in youth, the tree is a decided light-demander. It is comparatively short-lived; its rapid growth enables it to push its way through gaps till it reaches a height of 30–40 ft. or more, after which it is overtaken and suppressed by larger and longer-lived trees. It is a useful nurse for the sal, but requires to be cut out where it tends to get the upper hand. It is fairly frost-hardy, both in the seedling stage and later: although it suffered to some extent in the severe frost of 1905 in northern India, it escaped more lightly than many other species.

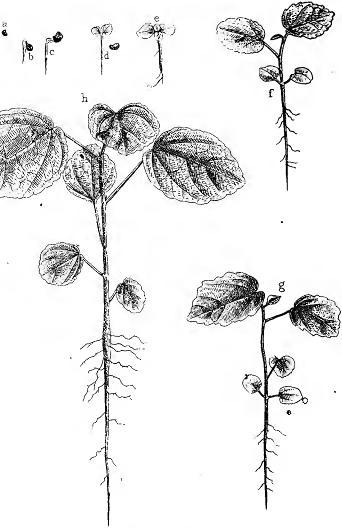

FIG. 65. *Kydia calycina.* Seedling × ¾.
a, seed; *b–d*, germination stages *e–h*, development of seedling to end of first season.

In the abnormal drought of 1907 and 1908, which caused severe damage to the sal forests of Oudh, it proved to be a decidedly hardy species.

It coppices well and produces root-suckers. The average number of coppice-shoots per stool, obtained from countings in coppice coupes in Gonda and Gorakhpur, United Provinces, and compared with sal and *Terminalia tomentosa* in the same coupes, was found to be as follows:

Age		2 yrs.	3 yrs.	5 yrs.	9 yrs.	11 yrs.	13 yrs.
Average No. of shoots per stool.	*Kydia calycina*	1·7	1	1·33	3	1	1
	Shorea robusta	1·8	1·11	1·28	1·34	1·36	1·18
	Terminalia tomentosa	4·7	—	2·53	2·46	1	—

Natural reproduction. Although the seeds have a comparatively low germinative power they are produced in large quantities. Experiments at Dehra Dun indicate that germination is far more successful in fairly moist places shaded from the sun than in dry open situations, where the seed usually fails to germinate. Under natural conditions in the early rains the light seeds are often washed into heaps mixed with dead leaves and loose soil; here they obtain conditions favourable to germination, which takes place during the first two months of the rains. The seedlings are very liable to damage by crickets, which bite the stems off and kill the seedlings. Although the development of the seedling is slow during the first season, it is vigorous during the second and subsequent years, in consequence of which the tree tends to become invasive under favourable conditions.

Artificial reproduction. Experiments at Dehra Dun showed that direct sowing does not give much success owing to the low germinative power of the seed. Transplanting is successful if carried out in the first rains with seedlings 2–3 in. high raised in seed-beds. In the second rains plants raised in the nursery are too large to transplant successfully, either with entire roots or with pruned stems and roots.

Rate of growth. The rate of growth is rapid. Natural untended seedlings in an experimental plot near Kotdwara in the United Provinces attained a height of 25 to 30 ft. in five years. In coppice coupes two years old in Gonda division, United Provinces, out of 17 species it was found to be surpassed by one species only, namely *Careya arborea*, which had coppice-shoots averaging 12 ft. in height as against 10·6 ft. for *Kydia* and 7·6 ft. for sal. In one-year-old coppice coupes in Bhandara, Central Provinces, the average height of *Kydia* shoots was 5 ft. 7 in., other measurements being: teak 7 ft. 1 in., *Xylia* 6 ft. 8 in., *Acacia Catechu* and *Lagerstroemia parviflora* 6 ft. 4 in., *Diospyros Melanoxylon* 5 ft. 1 in., and *Bassia latifolia* 4 ft. 3 in. Measurements recorded by Mr. A. F. Broun in coppice coupes at Bullawala, Dehra Dun, in 1886, gave the following results for *Kydia* and sal:

Age		8 yrs.	9 yrs.	9 yrs.	10 yrs.
Average height	*Kydia*	18 ft. 6 in.	17 ft. 5 in.	15 ft.	18 ft. 2 in.
	Sal	16 ft. 2 in.	13 ft. 6 in.	16 ft.	11 ft. 10 in.
Average girth	*Kydia*	6·9 in	9·7 in.	7 in.	7·4 in.
	Sal	8·3 in.	8·7 in.	8·6 in.	5·9 in.

It is probable that the tree reaches its maximum dimensions at a comparatively early age, though the exact age has not been determined.

3. THESPESIA, Correa.

Thespesia populnea, Corr. Tulip tree, portia tree. Vern. ***Poresh, dumbla,*** Beng.; *Bhendi*, Mar.; *Huvarasi*, Kan.; *Portia. pursa*, Tam.

A small or moderate-sized evergreen tree of the coast forests of India and Burma, largely planted as a roadside tree in tropical regions and recognized by its large yellow flowers with purple centres, its cordate leaves, and the black turban-shaped capsules which remain long on the tree. It prefers light porous soil. It is easily raised from seed or from cuttings, and grows quickly. Cuttings of all sizes strike well, but trees raised from large cuttings are said to be short-lived and liable to decay, and it is preferable to raise plants from small cuttings put down in the nursery. It flowers more or less throughout the year, but chiefly in the cold season.

4. ERIODENDRON, DC.

Eriodendron anfractuosum, DC. White cotton tree, kapok tree.

A moderate-sized soft-wooded deciduous tree with whorled horizontal branches and digitate leaves; stems of young trees armed with conical prickles. The tree is indigenous in the Andamans, the Malay Peninsula and Archipelago, in tropical America, and possibly but doubtfully so in the west of the Indian Peninsula: it is often planted. Its fruits furnish a silk-cotton (kapok) of better quality than that of *Bombax malabaricum*. The tree can be propagated from seed or from cuttings. An article in the *Bulletin of the Imperial Institute*, vol. ix, No. 2 (1911), p. 121, describes the cultivation of the tree in Java for the sake of its silk-cotton. The seed is sown in the nursery in drills 10 to 12 in. apart, and only lightly covered with earth. The seedlings are shaded until about 5 or 6 in. high and then exposed to the sun: they are planted out when eight to twelve months old, a spacing of about 18 ft. by 18 ft. being recommended. Before transplanting it is advisable to strip off the leaves and prune the stem down to a height of 1½ to 2 ft., and also to prune down the chief roots to some extent. During the early years of the plantation other plants can be cultivated between the young trees; in Java it is customary to grow pepper in this way, but it should not be planted before the kapok trees are three or four years old. The trees begin to bear in the third or fourth year, but sometimes not till later: a large crop is never obtained until the sixth year. A large tree produces 1,000 to 1,500 fruits per annum, each of which contains about 0·7 to 1·2 grammes of dry fibre. Hence on an average a well-developed tree may be expected to produce an annual yield of ¾ to 1¼ kilograms (about 1½ to 2¾ lb.) of clean fibre. In Java the tree flowers in April–May, and the fruits ripen in October–November: in India it flowers in December–January, and the fruits ripen in March–April. The fruits are collected when they are just beginning to open, by means of a long bamboo pole bearing a small hook at the upper end, and are placed in the sun until they open, when the seeds and fibre are picked out and then separated by beating or by means of a simple machine: the device described above (p. 137) for separating the seed from the floss of *Bombax malabaricum* would be suitable.

5. ADANSONIA, Linn.

Adansonia digitata, Linn. Baobab, Monkey bread tree.

A tropical African soft-wooded tree which has been introduced into India. Its growth is rapid, and it is remarkable chiefly for the enormous thickness of its trunk, which tapers upwards and divides into large limbs.

6. DURIO, Linn.

Durio zibethinus, Linn. Durian. Vern. *Duyin*, Burm.

A large handsome pyramidal evergreen tree, indigenous in the Malay Archipelago and extensively cultivated in Tenasserim. It is celebrated for its large prickly fruits, which have a most offensive odour. The cream-coloured pulp surrounding the seeds is considered by some to be a great delicacy. The seeds are large, about twelve weighing 1 lb.; they soon lose their vitality.

7. CULLENIA, Wight.

Cullenia excelsa, Wight. Vern. *Vedupla*, Tam.; *Karayani*, Mal.

A moderate-sized to large evergreen tree, pyramidal in shape, and somewhat resembling the durian in habit, indigenous in the Western Ghats from Coorg southwards and in Ceylon. The fruit, which is not edible like the durian, is the size of a large orange, and is densely covered with prickles; it does not possess the offensive odour of the durian. The seeds are few, 1·3 in. long, brown, shining, with a hard testa, surrounded by a large fleshy white arillus, about 40–45 weighing 1 lb.; they are somewhat perishable.

ORDER XI. STERCULIACEAE

This order is of considerable forest importance, furnishing besides fibre-yielding trees certain species with good timbers.

Genera 1. STERCULIA, Linn.; 2. HERITIERA, Aiton; 3. PTEROSPERMUM, Schreber; 4. HELICTERES, Linn.

1. STERCULIA, Linn.

Soft-wooded trees with timber of little value, but some of which yield useful bast fibres or gums: there are over twenty species in India, most of which are deciduous.

Species 1. *S. urens*, Roxb.; 2. *S. villosa*, Roxb.; 3. *S. alata*, Roxb.; 4. *S. foetida*, Linn.

1. **Sterculia urens.** Roxb. Vern. *Gulu*, *kulu*, *gulur*, Hind.; *Karai*, *kandol*, Mar.

A moderate-sized to large deciduous tree with smooth greenish grey or white bark peeling in large papery exfoliations. It is characteristic of dry open forests, chiefly on stony and rocky hills, in northern and central India, the Deccan, Rajputana, and Chota Nagpur, usually associated with *Boswellia serrata* and often gregarious; it also occurs on the west coast on rocky ground in North Kanara and the Konkan. In Burma it is found in dry upper mixed forests in hilly country. In India it is leafless from November–December till about May, and the gaunt white stems with stiff spreading **branches are** a somewhat weird sight. It flowers from December to March, the panicles of flowers appearing at the ends of the leafless branches; the red follicles, covered with stinging bristles, ripen about April. The tree is useful for reclothing bare rocky ground: it also yields a gum.

2. **Sterculia villosa**, Roxb. Vern. *Udal*, Hind.: *Sarda*, Mar.; *Shawni*, Burm.

A large deciduous tree with grey or brown bark covered with corky nodules, and branches showing large leaf-scars; it is common in deciduous forests throughout the greater part of India and Burma. It sometimes attains very large dimensions, with a straight clean bole: Mr. A. Rodger records a tree 14 ft. in girth in the Ruby Mines district of Upper Burma. In the Bengal Duars some fine specimens are to be seen in the drier types of forest on deep gravel formation near the base of the outer hills associated with *Shorea robusta*, *Lagerstroemia parviflora*, *Cedrela Toona*, *Bombax malabaricum*, *Albizzia procera*, *Terminalia belerica*, *Gmelina arborea*, and other deciduous trees. The large long-stalked deeply lobed leaves fall in November–December, turning first yellow, then brown and shrivelling up, and the tree remains leafless till May or June. In January–February the clusters of drooping panicles of yellowish flowers are conspicuous at the ends of the bare branches, the five-lobed calyces, about 0·5 in. in diameter, yellow with a reddish centre, falling to the ground in quantity: the dry follicles of the previous year are often still on the tree at this time. The follicles ripen in April–May, their beautiful scarlet lining when they open giving them at first sight the appearance of flowers. The seeds germinate at the beginning of the rains, soon after falling: about 110–120 weigh 1 oz. The seeds are somewhat perishable; a sample kept for one year showed a fertility of only 6 per cent. In soil which is stiff or too damp the seedlings are apt to rot off: a light sandy soil is most favourable to their establishment. Germination is hypogeous, the cotyledons remaining within the testa and developing short petioles from between which the plumule emerges: the early leaves are three-lobed. The tree coppices well and grows very rapidly. Natural seedlings in an experimental plot near Kotdwara, United Provinces, attained a height of 15 to 20 ft. in four to five years. The bast yields a strong fibre which is much in request for rough cordage; the cortex yields a white gum.

3. **Sterculia alata**, Roxb. Syn. *S. Haynii*, Bedd. Vern. *Tula*, Beng.; *Tattele mara*, Kan.; *Ana thondi*, Mal.; *Letkôk*, Burm.

A very large evergreen tree with smooth grey bark, a straight cylindrical bole, and large simple entire leaves; large trees are often buttressed at the base. It occurs in the Tista valley, Sikkim, the Duars (not common), Assam, Chittagong, Lower Burma, the Andamans, the west coast of India from North Kanara southwards, Tinnevelly and Travancore. It is found sporadically in moist situations in tropical evergreen forest, where it is one of the largest trees met with, often towering over the surrounding vegetation. The flowers appear in February–March, and the large globose woody follicles ripen in the cold season: the seeds are winged, about 2·5 in. long, some 20–30 being packed closely in each follicle. Natural seedlings and saplings are sometimes fairly numerous in the neighbourhood of seed-bearers, and are easily recognized from their large entire ovate leaves with a cordate base and three or five basal nerves: they are capable of establishing themselves in the forest under fairly dense shade. The tree is much cultivated for ornament and as an avenue tree, and does well even as far north as Dehra Dun and Lahore; it suffered severely, however, from the abnormal frost of 1905, trees about 3 ft. in girth being killed down, though they subsequently recovered from the base. The tree coppices well.

4. **Sterculia foetida**, Linn. Vern. *Jangli badam*, Hind.: *Pinari*, Tam.: *Letkôk, shawbyu*, Burm.

A large deciduous tree with whitish bark, long-stalked digitate leaves, and flowers with an offensive odour, appearing when the tree is leafless: the seeds are roasted and eaten. The tree is indigenous in western and southern India and Burma, and is sometimes cultivated. It is easily raised from seed, the seedlings growing rapidly and forming long taproots; they can be transplanted during the first rains without much difficulty. The seedlings will not stand the cold of northern India.

2. HERITIERA, Aiton.

This genus contains five (or more?) Indian species, of which two, *H. Fomes*, Buch., and *H. littoralis*, Dryander, are littoral and the others are inland species. The most important timber tree of the genus is *H. Fomes*, Buch., the *sundri* of the Sundarbans.

Species 1. *H. Fomes*, Buch.; 2. *H. littoralis*, Dryand.; 3. *H. Papilio*, Bedd.

1. **Heritiera Fomes**, Buch. Syn. *H. minor*, Roxb. Vern. *Sundri*. *sunder*. Beng.; *Pinlè-kanazo, ye-kanazo*. Burm.; *Kazo*, Arakan.

A gregarious evergreen tree with buttressed stem and grey longitudinally cracked bark, moderate sized in the Sundarbans, attaining larger dimensions in Burma. In the Sundarbans trees were at one time found up to 6 ft. in girth, and even stems 7 ft. in girth have been recorded among logs obtained from this tract, but owing to heavy fellings and the difficulties experienced in controlling them, trees over 3 ft. in girth are now by no means common. A tree 8 ft. in girth was measured in 1915 in the Nangli coupe, compartment 24 of the Sundarbans. The tree grows to a height of 50 to 80 ft., according to locality. The wood is very hard, tough, and elastic, and is much in demand for boat-building, buggy-shafts, building, and other purposes.

Distribution and habitat. The Sundarbans forests of the Ganges–Brahmaputra delta in Bengal, the coasts of Chittagong, Arakan, and Burma, ascending the rivers within tidal limits. On the Arakan and Bassein coasts of Burma there are extensive *sundri* forests, which have hitherto been little worked, while in Tenasserim there are belts of *sundri* along many of the tidal creeks and round the islands, especially in the Mergui district. These littoral forests in general comprise three distinct belts, an outer fringe near the sea consisting of pure mangrove forest; an intermediate belt of various trees mixed with mangroves, with or without *sundri*; and an inner belt of pure or nearly pure *sundri*. In the Sundarbans the outer pure mangrove belt is absent or very limited, though *Ceriops* forms nearly pure forest on the higher ground near the sea. As illustrating the gregarious nature of the tree, enumerations by Mr. J. D. Hamilton in eleven sample plots in *sundri* forest in Arakan showed the following average stock :

Seedlings	357 per acre.
Trees 1–2 ft. in girth	104 ,,
,, 2–3 ft. ,,	52 ,,
,, 3–4 ft. ,,	23 ,,
,, 4–5 ft. ,,	8 ,,
,, 5 ft. and over in girth	2·7 ,,

Further enumerations in the Sundarbans forests of Bengal are quoted below.

As regards climatic requirements, the *sundri* grows in regions with a warm equable climate and a fairly heavy rainfall. The following meteorological statistics refer to the principal localities in which *sundri* forests are found :

Locality.	Absolute maximum temperature. Fahr.	Absolute minimum temperature. Fahr.	Normal rainfall. in.
Sundarbans	102°	45°	63–88
Chittagong and Arakan coast .	99°–100°	45°–48°	105–210
Bassein coast	100°	55°–64°	110–117
S. Tenasserim coast . . .	98°–100°	44°–48°	160–200 or more.

The Sundarbans forests. The famous Sundarbans tract of Bengal, in which the *sundri* is the most important species, is one of the most valuable forest estates in India ; it supplies with timber, firewood, and other produce not only the surrounding districts but also the town of Calcutta. This tract forms the southern portion of the Gangetic delta, bordering on the Bay of Bengal and extending 180 miles east to west and 80 miles north to south. The Government forests of this tract are confined to the Twenty-four Parganas and Khulna districts : the reserved forests comprise an area of 1,703 square miles, of which 594 square miles are water-channels, while the protected forests, portions of which have been disforested from time to time, at present comprise an area of 1,711 square miles. Apart from the Government forests there is an adjoining tract of forest in the Backerganj district in process of being cleared for cultivation.

The forests occupy a flat plain of recent alluvial origin formed, and still in process of formation, by the gradual deposition of silt brought down by the Ganges and Brahmaputra rivers, and intersected by a network of rivers and channels. The larger estuaries, which run in a general north to south direction, are more than a mile wide where they enter the forest and three to four miles in width where they debouch into the Bay of Bengal. These estuaries or rivers are old beds of the Ganges, which has gradually trended eastwards forming new channels, and these old beds would long since have silted up but for tidal action : their upper reaches, traversing cultivated lands, are gradually silting up, preventing fresh water from passing down them, with the result that their lower reaches are tending to become more and more salt. Apart from the main estuaries there are innumerable side channels known as *khals*, some of which (*barani khals*) lead from estuary to estuary, and others (*mara khals*) gradually branch into smaller channels until they disappear in the forest. Many of the smaller *khals* have their origin in depressions of varying size known as *bhils*, which as a rule are not well stocked with tree growth. The *khals* are kept open by the action of the spring tides, which at high water cover the whole country to a depth of a foot or more, and in receding scour out the channels and prevent them from silting up. On cultivated lands the construction of bunds to keep out the salt water prevents this tidal action and causes the channels to silt up. During the dry season the influence of the tides is felt far up the channels, but in the rainy season tidal action is nullified by the constant stream of fresh water seawards. The *khals* are the natural highways for the extraction of forest produce, which is all brought out by boat, the tidal currents being utilized for conveying the boats in one direction or the other. The erosion which takes place along the banks of some of the larger rivers is counterbalanced by fresh deposits of alluvium in the form of low islands usually near the centre of the mouths of the estuaries: these islands or banks, locally known as *churs*, vary in composition from hard sand along the sea-face to soft mud farther inland, and frequently form barriers across the mouths of the larger rivers, especially towards the east of the Sundarbans, constituting a danger to navigation. When these banks become islands they intercept the seeds of trees and other plants carried down by water, and thus in time become covered with forest growth and merge into the forest tract as a whole.

The lowest portion of the Sundarbans lies to the west of the Pussur river in the northern part of the forests, where there are many low-lying *bhil* areas. Some of the strips near the sea never become inundated, even at spring tides, and it is noteworthy that during spring tides deer and other animals congregate on the higher ground towards the sea-face in order to escape the floods. The lower portions of the Sundarbans are flooded at every high tide, fresh deposits being thus accumulated by slow degrees until the ground gets above the reach of ordinary tides and is covered only by spring tides, which inundate the whole of the Sundarbans forest tract except the highest ground near the sea. The vegetation of the Sundarbans comprises numerous species of trees, of which the principal, besides *sundri*, are *Excaecaria Agallocha*, *Sonneratia apetala*, *S. acida*, *Carapa moluccensis*, *C. obovata*, *Amoora cucullata*, *Aegiceras majus*, *Cynometra ramiflora*, *Avicennia officinalis*, and the mangroves *Ceriops Candolleana*, *C. Roxburghiana*, *Kandelia Rheedii*, *Rhizophora mucronata*, and *Bruguiera gymnorhiza*. *Pongamia glabra* is found along sand-hills near the sea, and mango, *Diospyros Embryopteris*, and a few other trees occur on former village sites. On newly formed islands, flooded by every tide, *Sonneratia* usually springs up first, followed by *Avicennia* and the palm *Nipa fruticans*. As the ground rises other trees make their appearance, the most prevalent, though one of the later species to appear, being *Excaecaria Agallocha*. As the level rises by accretion, and the land is only occasionally flooded by the tide, the *sundri* makes its appearance. It is not uncommon to find *sundri* springing up under large dying *Sonneratia* trees, the suckers of which have become silted up. In the western or lower half of the Sundarbans there is little or no *sundri*. In the eastern half it is scarce near the sea-face except in the most easterly portions, but on proceeding inland it increases in quantity until pure or nearly pure *sundri* forests are met with. On the existence of two separate types or qualities of *sundri* forest Mr. Trafford[1] remarks: '**Observation of** sample plots and measurements of trees have brought to light the **existence** of two types of *sundri* forest which may be described as (*a*) **the salt-water** type and (*b*) the fresh-water type. The former is found in **the area near the** sea face and on the high ground which forms the banks of **all large and** medium-sized *khals* throughout the forests. The growth of **the salt-water** type is extremely slow, and the average figures yielded by **one sample plot** show that it is only $\frac{1}{56}$ of a foot per annum. So universal **is the presence** of this type along the banks of streams navigable by **steam launches, that** any one traversing the forest without going into the smaller ***khals* would** receive the impression that there are few or no good *sundri* **trees in the** Sundarbans. The fresh-water type of forest predominates **at a distance of** from one to three hundred yards from the edge of all *khals*. **This forest** consists of straight tolerably tall stems of from one to two **and a half feet in** girth, growing fairly compactly with little or no undergrowth, **and in places** containing over three hundred trees per acre. The growth of **the *sundri* is** best where the level of the ground is intermediate between **the high strip** along the *khals* and the low *bhil* areas farthest away from **them; the quality** is usually also good towards the sources of the smaller *khals*. **The proportion** of *sundri* in the crop varies greatly, linear valuation surveys showing **a variation** of 1 to 240 *sundri* trees 1½ ft. in girth and over per acre **according to** the degree to which the *sundri* is mixed with other species or **forms more or** less pure crops. Enumerations by Mr. A. L. Home, recorded **in the Bengal** Forest Report for 1873–4, showed an average per acre of 2,487 **seedlings and** saplings under 3 ft. in girth and 182 trees 3 ft. in girth **and over; these figures** must refer to pure *sundri* crops, and not to a general average such as is obtained from linear valuation surveys traversing various types of forest. **On the *bhils*** or depressions the *sundri* trees, where present, **tend to deteriorate rapidly** and to die off.

In dense forest of *sundri* undergrowth is practically absent, **but in certain** portions of the area, particularly in low-lying places, there is an undergrowth of varying density, sometimes thick and almost impenetrable, of which the principal species are *Nipa fruticans* (vern. *golpatta*), a small palm much in request for thatching, and common along watercourses, in *bhils*, and other open places; *Phoenix paludosa* (vern. *hantal*), a palm forming impenetrable prickly masses usually on the higher ground where the forest has been opened out; *Hibiscus tiliaceus* (vern. *bhola*), a climber growing to a height of about 10 ft. and forming dense matted thickets; *Pandanus odoratissimus* (vern. ***kewa***), forming a troublesome prickly undergrowth under fairly dense shade; ***Acanthus ilicifolius*** (vern. *hargoza*), common near the sea-face and forming dense prickly masses; *Derris sinuata* (vern. *sundrilota*), a common creeper, usually in the neighbourhood of *khals*; and *Acrostichum aureum* (vern. ***udoban***), a large-leaved fern forming a very common undergrowth, often to the exclusion of almost all other plants; areas covered with this fern are favourite haunts of the man-eating tigers which infest the Sundarbans.

Fig. 64 gives an idea of a *sundri* pole crop in the Sundarbans which has just been thinned.

---

[1] Working Plan for the Forests of the Sundarbans Division, 1911.

Spread and germination of seed. The fruit carpels (Fig. 66, *a*), 1·5–2 in. long by 1–1·5 in. broad, 12–15 weighing 1 oz., ripen in July–August and fall to the ground, or in the case of trees growing near the banks of water-channels they fall into the water, and being buoyant are borne along in quantities on the surface by the tidal currents until stranded: in the spring tides of August the masses of seeds on the surface of the water have the appearance of immense rafts, so closely do they float together. The seed is liable to the attacks of an insect which may destroy much of the early part of the crop. Germination (Fig. 66, *b*–*e*), which is hypogeous, takes place very soon after the carpels fall. The thick fleshy cotyledons remain within the fibrous wall of the carpel; the stout radicle appears first, the petioles of the cotyledons meanwhile elongating so as to enable the plumule to emerge: the latter soon appears, the young shoot elongating and arching until free, when it straightens.

The seedling (Fig. 66).

Roots: primary root moderately long, thick, terete, tapering: lateral roots numerous, long, fibrous, distributed down the main root but most numerous on the upper part. *Hypocotyl* distinct from the root, 0·4–0·5 in. long by 0·2 in. or more in diameter, pink to light brown, subterranean. *Cotyledons* subterranean: petiole 0·4–0·5 in. long by 0·1–0·15 in. in diameter, terete or slightly compressed, woolly tomentose, curved to one side of stem: lamina 1·1–1·3 in. in length and breadth, thick, fleshy, orbicular, apex rounded, base sagittate, pinkish white, glabrous, outer surface convex, smooth inner surface concave or irregularly undulating. *Stem* erect, terete, light greenish brown, covered with silvery scales and lenticels, leafless for several nodes and for a length of 7–18 in. or more; internodes chiefly 0·5–1·5 in. long, the earlier ones often longer, up to 6 in. or more. *Leaves* simple, alternate, the first few abortive. Stipules 0·1–0·15 in. long, acuminate, caducous. Petiole 0·1–0·2 in. long, stellate pubescent. Lamina 2·5–6 in. by 0·4–1 in., oblong lanceolate, acute or acuminate, entire, coriaceous, upper side green, glabrous or with scattered silvery scales, lower side covered with silvery scales.

The early development of the seedling is very rapid. Within a month the stem may reach a height of 18 in. or more, and the stout taproot a length of 7 or 8 in., with a number of fairly long lateral roots. This early development enables the seedling to obtain a footing in spite of floods, and it is interesting to note that there may be a considerable length of bare stem with only scaly abortive leaves, the normal leaves being borne in the upper part of the stem where they are likely to be above the level of the water. During the rapid development of the leafless stem the plant receives its food from the starchy cotyledons. A similar early development is noticeable in the case of *Carapa moluccensis*, and it is possible that a further study of the development of seedlings of littoral species may reveal other instances of the same kind.

Silvicultural characters. The *sundri* is a moderate light-demander, enduring more shade in youth than it does later. The general habits of the tree have already been indicated in the description of the Sundarbans forests above, and in particular it may be noted that the tree avoids the lowest and newest land subjected to submergence by every high tide, and seeks the higher ground which is only flooded by brackish water for a few days twice a month. It does not flourish on the highest ground, which is often very saline, but grows best on land intermediate in level between the highest and the lowest.

It is a freshwater rather than a salt-water species, and avoids areas which are highly saline or are liable to flooding by pure salt water. On the more saline areas the trees tend to deteriorate and die, or while still of comparatively small dimensions to reach a stage, locally known as *pukka*, where further growth practically ceases. Mr. Trafford points out that this want of vigour may be traced to the deleterious effect of the salt in the soil, which is more pronounced on high land than on land exposed to frequent inundation by the tide. During the dry season the evaporation of water from high ground causes the salt held in solution to be deposited at or near the surface of the soil, which thus becomes saturated with salt. This theory is borne out by the fact that the growth of trees generally, and of *sundri* in particular, is more rapid towards the east of the Sundarbans, where fresh water persists for a good part of the year, than in the west, where the water-channels remain more or less salt throughout the year. Probably, however, the mere silting up of the root-system, preventing soil-aeration, accounts in part for the deterioration or death of the trees. The root-system of the *sundri* is decidedly abnormal. The roots do not penetrate very deep, but spread laterally not far below the surface, sending up numerous blind suckers or pneumatophores (locally known as *shoolas*) from a few inches to over a foot above the surface of the ground; these suckers, which are believed to be breathing organs, resemble inverted tent-pegs and cover the ground in the neighbourhood of the trees, making progression difficult (see Fig. 64). The coppicing power of the *sundri* varies considerably. So far as observations go, coppice reproduction is poor in places where the trees show the best development and most vigorous growth, as in the freshwater type of forest, whereas on the saline soil of the salt-water type and on drier ground, where the growth and development of the trees is poor, coppice growth is remarkably vigorous; possibly this may be due in part to the fact that on drier ground less energy is spent by the trees in producing suckers. For successful coppice growth abundance of light is required. The *sundri* pollards well. Fire, frost, and grazing do not occur in the Sundarbans forests. Severe damage is done periodically at fairly long intervals by cyclones, which uproot the trees, break the tops off, or tear off the branches. The last severe cyclone occurred in October 1909 and caused immense damage: the direction in which the trees were thrown showed that at the height of the storm the wind blew from east to west.

NATURAL REPRODUCTION. The seeds, as already noted, ripen and fall in the rainy season and are transported in large quantities by water action. The forces operating on its dissemination are the strong floods of river water and local rain seawards, the spring tides which occur at this season, and the monsoon winds blowing from the south-west. The last factor is evidently an important one, since seedlings are often found in greatest quantity on the north and east banks of the larger rivers and water-channels where they have been washed by the waves formed by the monsoon winds. Where seed has been stranded in quantity seedlings appear in enormous numbers, forming thickets of great density.

Experience has shown that judicious thinnings greatly stimulate the establishment of seedlings. Regeneration, however, appears to be more successful under moderate cover than where the canopy is too heavily opened out, and hence the thinnings should not be too drastic ; heavy cover, on the other hand, prevents the establishment of natural regeneration. Where clearings are made in the *sundri* tracts regeneration is a very uncertain matter, since unless the direction of the flood water is favourable the seed has no means of being conveyed to the cleared areas ; in any case it is by no means certain that seedlings will be able to establish themselves on open blanks.

SILVICULTURAL TREATMENT. The treatment at present applied to the *sundri* tracts of the Sundarbans under the working plan of 1911 is based on the beneficial effects of thinnings on the development of the crop and on natural reproduction, the other factors taken into consideration being the large areas to be dealt with, the difficulty of supervising felling, and the deterioration of the forests as a result of the earlier working in vogue some years previously. The treatment now in force is provisional, and consists of improvement fellings by area combined with thinnings under a felling cycle of forty years, the exploitable girth for sound *sundri* being fixed at 3½ ft. In the salt-water type, where the growth is slow, one felling in forty years is considered sufficient, but in the freshwater type, where the growth is considerably faster, a thinning will precede the main felling at as long an interval as is practicable—sixteen years being fixed in the present working plan—while subsidiary thinnings will be executed as required in the more accessible areas.

The value of judicious thinnings in increasing the rate of growth of the *sundri* has been fully demonstrated in the Sundarbans : if they are carried out too drastically, however, the trees tend to produce epicormic branches. In the cyclone of 1909 thinned areas in exposed situations on the banks of watercourses suffered severely, whereas many heavily thinned areas sheltered by forest on the east escaped with little or no damage : the state of the ground, however, appeared to have more effect on the degree of damage than any other factor, the number of trees blown down being greater on the softer and wetter ground than on the harder and drier ground.

RATE OF GROWTH. Measurements extending over sixteen years in four sample plots in the Sundarbans show a mean annual girth increment of 0·5 in. in the best plot, of the freshwater type, as against 0·21 in. in the worst plot, of the salt-water type. This indicates that the growth is decidedly slow, though measurements in adjacent thinned and unthinned sample plots prove that thinnings result in a considerable acceleration of girth increment. Statistics regarding the rate of growth of coppice-shoots are not available : Mr. Trafford notes that coppice-shoots four years old in the Slanekhali block of the Sundarbans had a maximum height of 8 ft.

2. **Heritiera littoralis,** Dryand. Looking-glass tree. Vern. *Pinlè-kanazo*. Burm. ; ***Mawlda***, And. ; *Chandmara*, Kan. : *Sundrichand*, Mar. : *Chomuntiri*, Tam.

A moderate-sized gregarious evergreen tree with grey longitudinally furrowed bark, found in the littoral forests of Burma, the Andamans, the Indian Peninsula, and Ceylon. Although commonly found along the sea-coast it succeeds fairly well in Ceylon up to about 1,500 ft. elevation. In the Andamans it grows in the littoral zone down to the level of high tide, and in places where the mangrove forests are absent, and also to some extent on the flat muddy ground close to the mangrove swamps. Its chief companions are

Cynometra ramiflora, Erythrina indica, Mimusops littoralis, ***Hibiscus tiliaceus***, *Thespesia populnea, Terminalia Catappa, Carapa moluccensis*, and ***Calophyllum Inophyllum***. Talbot says the roots do not apparently develop blind root-suckers like the Sundarbans species.

3. **Heritiera Papilio**, Bedd. (possibly including *H. acuminata*, Wall., a tree of the Khasi hills).

A very large tree of the evergreen forests of Tinnevelly and Travancore between 2,000 and 4,000 ft.; its most important associates are ***Mesua ferrea***, *Vitex altissima, Litsaea zeylanica*, and *Bischoffia javanica*.

3. PTEROSPERMUM, Schreber.

Several trees of this genus are planted for ornament, and are interesting owing to the variety in the form of their leaves, their showy usually white flowers, five-valved woody capsules, and winged seeds: the capsules sometimes ripen at the time the tree is in flower, taking a year to mature, and usually persist for some time after ripening. Some species (e. g. ***P. acerifolium***, Willd., and *P. semisagittatum*, Ham.) are known to produce root-suckers freely; this may possibly be a general characteristic of the genus.

Pterospermum acerifolium, Willd. Vern. *Mayeng*, Jaunsar; ***Hati-paila***, Nep.; *Kanak-champa*, Beng.; *Taung petwun*, Burm.

A large handsome evergreen tree with thin grey smooth bark and large round somewhat variable deeply cordate or peltate leaves, dark green above and white tomentose beneath. Wood moderately hard, reddish, of good quality, suitable for carpentry, and sometimes used for planking.

Distribution and habitat. The sub-Himalayan tract and outer Himalayan valleys and hills up to 4,000 ft., Bengal, Chittagong, Khasi hills, Manipur, Burma, North Kanara. Often planted for ornament. The tree is found wild in a variety of situations. In the Dehra Dun valley it is common in swamp forests associated with *Trewia nudiflora, Diospyros* ***Embryopteris, Eugenia*** *Jambolana, Cedrela Toona, Ficus glomerata, Putranjiva* ***Roxburghii, Phoebe*** *lanceolata, Machilus Gamblei*, and sometimes ***Bischoffia javanica*** and ***Carallia*** *lucida*. In the outer Himalaya it is found along river-banks, but also ascends the hill-sides, where it is sometimes seen even in fairly dry situations, though in such places the subsoil is moist, overlying water-bearing rocks. In Burma it is common along streams in tropical and moist upper mixed forests. Talbot says it is found on the southern *ghats* of North Kanara in evergreen rain-forests, and that it is abundant in the Devimone forests. In its natural habitat the absolute maximum shade temperature varies from 95° to 110° F., the absolute minimum from 30° to 60° F., and the normal rainfall from 55 to 150 in. or more.

Flowering and fruiting. The large scented white flowers appear from March to June, and the capsules ripen a year later, opening about the time the tree is in flower. The capsules are 4–6 in. long, dark brown, tomentose, woody, five-valved. The seeds (Fig. 67, *a*) are brown, compressed, with large membranous terminal wings, the whole being 1·3–2 in. long: they are thus adapted for distribution by wind. The fertility of the seed is usually good, and it retains its vitality well for one year: tests made with samples of seed

kept for a year showed a fertility of 70 per cent., while seed kept for two years had a fertility of only 10 per cent.

Germination (Fig. 67, *b–f*). Epigeous. The radicle emerges from the end of the seed opposite the wing and descends. The hypocotyl elongates, sometimes with slight arching, and carries above ground the cotyledons, which are much crumpled before expansion. The testa is either left on or under the ground or is carried up over the cotyledons, falling with their expansion.

The seedling (Fig. 67).

Roots: primary root long, terete, tapering, greyish brown, woody: lateral roots numerous, fine, fibrous, distributed down main root. *Hypocotyl* distinct from the root, 1·5–1·8 in. long, terete or slightly compressed, fusiform, white turning green, tomentose. *Cotyledons*: petiole 0·15–0·2 in. long, tomentose: lamina 0·7–0·8 in. by 0·6–0·9 in., foliaceous, sub-orbicular, entire or bifid, palmately 5-veined from the base. *Stem* erect, terete, white tomentose; internodes 0·1–0·5 in. long. *Leaves* simple, alternate. Stipules 0·1 in. long, linear. Petiole (early leaves) 0·5–1·2 in. long, tomentose. Lamina (early leaves) 1·8–3 in. by 1–2 in., ovate acuminate, peltate, entire or irregularly or obscurely toothed, dark green and glabrous or stellate pubescent above, white tomentose beneath, radiately 7- or 8-veined.

The development of the seedling during the first season is slow, a maximum height of 6 in. with a taproot up to 8 or 10 in. long being as a rule attained even if regular watering and weeding are carried out. During the second season, however, the growth under favourable conditions is very rapid, nursery-raised plants which have not been transplanted attaining a height of as much as 4½ ft. and producing large leaves. By the end of the third season the height of such plants may increase to as much as 13 ft. Transplanting appears to check the growth, transplanted seedlings often showing very little stem development in the second season, though the taproot may attain a length of as much as 2 ft. The same applies to seedlings which remain unweeded and unwatered, these often being not more than 3 in. high at the end of the second season, if they are fortunate enough to survive as long. The growth of seedlings ceases in the cold season (northern India). Seedlings are decidedly frost-hardy, but are sensitive to drought.

Silvicultural characters. The tree is a moderate shade-bearer. It is fairly frost-hardy, but in the abnormal frost of 1905 in northern India it was slightly to badly damaged. The tree coppices well and produces root-suckers in abundance.

Natural reproduction. Experiments at Dehra Dun have shown that under natural conditions the seeds germinate early in the first rainy season after they fall, and that a considerable amount of soil moisture is necessary for the establishment of the seedlings, which are sensitive to drought and die off if they come up in situations exposed to a hot desiccating sun. A good deal of the natural regeneration seen in the forest consists of root-suckers.

Artificial reproduction. Experiments at Dehra Dun show that direct sowings kept weeded and watered produce the best results, the growth after the first season being very rapid. The tree is worth cultivating as an accessory species in irrigated plantations, by means of weeded line sowings. To obtain transplants the seed should be sown in drills in nursery beds in April or May, the beds being kept well watered and weeded. The seedlings can be transplanted without much difficulty during the first rains, in **July or August,** when they are about 3 in. high: transplanting in the second **rains is more** difficult and requires special care to prevent the stems **dying down. In either** case the growth of the plants is checked by transplanting, and **the development** for the first year or two is poor compared with that attained **by direct sowings** properly tended.

Rate of growth. After the seedling has established itself **and commenced** to shoot up growth is rapid. A height-growth of 6 ft. per **annum has been** attained by saplings in weeded and irrigated sowings at Dehra **Dun.**

4. HELICTERES, Linn.

Helicteres Isora, Linn. Vern. *Maror-phal,* Hind.

A large shrub with leaves resembling those of the hazel, **common and** often gregarious in many parts of India. In northern India the **red flowers** appear chiefly in July–August, and the fruits ripen in **December–January**; the latter consist of spirally twisted carpels which untwine **and split on** ripening, the small seeds thus escaping. The shrub coppices very well, **shooting** up rapidly again even if cut or burnt back annually; **in some places, as in** parts of the Siwalik tract, it becomes invasive, forming **a dense almost** impenetrable growth to the exclusion of other species. It yields **a good fibre.**

ORDER XII. TILIACEAE

This order contains a few timber trees of some importance **and many** accessory forest species.

Genera 1. Pentace, Hassk.; 2. **Berrya,** Roxb.; 3. **Grewia,** Linn.; 4. Echinocarpus, Blume.

1. PENTACE, Hassk.

Pentace burmanica, Kurz. Vern. *Thitka,* Burm.

A large evergreen tree of the tropical forests of Burma, **usually in hilly** country. Wood light red, moderately hard, somewhat **resembling mahogany** in texture and used for boat-building and carpentry. **According to Gamble** the growth is rapid, 3 to 4 rings per inch of radius representing **a mean annual** girth increment of 1·6 to 2·1 in.

2. BERRYA, Roxb.

Berrya Ammonilla, Roxb. Syn *B. mollis,* Wall. Trincomali-wood. Vern. *Petwun,* Burm.

A large deciduous tree with smooth pale thin bark, commonly attaining a height of 60–80 ft. and a girth of 6 ft. The leaves are broadly cordate. The wood is strong, elastic, and durable, and is used for building, shafts, carriage manufacture, agricultural implements, and other purposes; in Madras it is used for boat-building.

Distribution and habitat. Throughout Burma, in suitable localities, Ceylon, Little Coco Island (Prain). Often **planted in southern India. In** Burma it is found scattered in upper mixed deciduous forests, **chiefly of the** drier type, associated with teak, *Terminalia tomentosa*, ***Xylia dolabriformis,*** *Dalbergia cultrata*, *Homalium tomentosum*, and various other trees. It occurs to some extent in *indaing* (dry dipterocarp) forest associated with *Dipterocarpus tuberculatus*, *Pentacme suavis*, and *Shorea obtusa*. It also extends into the lower mixed deciduous forests of the plains, associated with teak, *Terminalia tomentosa*, *Lagerstroemia Flos-Reginae*, *Adina cordifolia*, *Stephegyne diversifolia*, *Adina sessilifolia*, *Terminalia belerica*, *Odina Wodier*, and other species. The tree is not gregarious, but occurs scattered in greater or less abundance. Enumerations in 1903–4 in the plains forests of the Tharrawaddy district, Burma, showed the average number of trees 3 ft. in girth and over per 100 acres to be 69 in the Satpôk reserve, 4 in the Sitkwin reserve, and 57 in the Thindawyo reserve; the total area enumerated was 20 square miles. These forests are on flat land, the soil being a rich alluvial loam with occasional pans of clay, where the tree-growth is poorer than elsewhere.

In its natural habitat in Burma the absolute maximum shade temperature varies from 100° to 110° F., the absolute minimum from 40° to 60° F., and the normal rainfall from 35 to 120 in. or more.

Leaf-shedding, flowering, and fruiting. The tree is leafless for a time in the hot season. The panicles of white flowers appear in the cold season and the capsules ripen in the hot season. The seeds are ovoid or sub-angular, 0·2–0·25 in. long, light brown, with a hard testa and a thin albumen.

Germination. Epigeous. The testa splits, and the radicle emerges and descends. The hypocotyl elongates, raising the cotyledons above ground: the testa and albumen are usually carried up over the cotyledons, falling with their expansion.

The seedling.

Roots: primary root moderately long, tapering: lateral roots numerous, fibrous, distributed down main root. *Hypocotyl* distinct from root, 1·6–2 in. long, tapering upwards, green, pubescent. *Cotyledons*: petiole 0·15–0·2 in. long, compressed laterally, pubescent: lamina 0·6–0·9 in. diameter, foliaceous, orbicular, entire, green, glabrescent, 5-veined from the base, the three central veins more prominent than the two lateral ones. *Stem* erect, terete or slightly compressed, tomentose. *Leaves*, first pair opposite, subsequent leaves alternate. Petiole 0·3–1 in. long, tomentose. Lamina 1–2 in. by 0·8–1·5 in., cordate, obtuse or acute, serrate, puberulous, 5-veined from the base.

The growth of the seedling is comparatively slow, a height of 3 to 9 in. being attained in the first season. In dry places the seedlings may die back for some years, showing little increase in height during the period. Seedlings raised at Dehra Dun have been found to be very subject to insect attacks, to which they succumb in their early stages.

Silvicultural characters. The silvicultural characters of the tree have not been studied in any detail. It is known to coppice and to produce root-suckers freely, particularly when felled.

Natural reproduction. The conditions which favour natural reproduction have not been sufficiently studied. Germination takes place early in the rains not long after the fall of the seed. Ordinarily the tree regenerates well, provided the canopy is open, as in the plains forests of the Tharrawaddy district, where in heavily felled areas there are numerous saplings. Mr. Walsh notes that in the Ruby Mines district the tree has difficulty in establishing itself, seedlings, or possibly root-suckers, being plentiful round each tree, but saplings and poles being scarce. In Burma natural reproduction is sometimes plentiful in abandoned *taungyas*. In 1914–15 reproduction is reported to have sprung up freely in the Yetkanzin reserve, North Toungoo, in a bamboo-flowered area, which had been fire-protected for many years and then burnt after the flowering of the bamboo.

3. GREWIA, Linn.

This genus is a large one, containing over thirty species, chiefly shrubs and climbers, with some small to moderate-sized trees. Some species are characteristic of dry or arid regions, for example *G. populifolia*, Vahl, a shrub; *G. salvifolia*, Heyne, a shrub or small tree; and *G. flavescens*, Juss., a large straggling shrub. *G. sapida*, Roxb., is a curious undershrub common on the grassy plains of the sub-Himalayan tract, ascending to 3,000 ft.; also found in Chota Nagpur and in Upper Burma. It has a woody root-stock from which new shoots are sent up each year after the old stems have been burnt back by the annual fires: the yellow flowers appear on the new shoots in the hot season, and the fruits ripen at the beginning of the following cold season. Some species of *Grewia* have strong elastic wood, used for shafts, shoulder-poles, bows, and other purposes for which elasticity is required. They coppice well, some species producing shoots of great vigour: many, possibly all, produce root-suckers. The fruits of several species are edible.

For a botanical examination of the Indian species of *Grewia* of forest importance see Hole in *Indian Forester*, xliii, 312.

Species 1. *G. oppositifolia*, Roxb.; 2. *G. laevigata*, Vahl; 3. *G. Hainesiana*, Hole; 4. *G. elastica*, Royle; 5. *G. tiliaefolia*, Vahl; 6. *G. Microcos*, Linn.

1. **Grewia oppositifolia**, Roxb. Vern. *Dhaman, biul, bhimal*, north-west Himalaya.

A moderate-sized deciduous tree with a short straight trunk and smooth grey bark, common on the outer hills of the western Himalaya and much planted near villages, where it is heavily lopped for cattle fodder: the bark is much used for making ropes. The tree is easily propagated from cuttings or from seed, and is hardy, growing on almost any situation in the outer hills. It is leafless for a short time in March–April. It flowers from March to June, sometimes at other seasons, and the fruits ripen from October to December. The edible drupe is one- to four-lobed, black when ripe. The growth, according to Gamble, is 7 rings per inch of radius, representing a mean annual girth increment of 0 9 in.

2. **Grewia laevigata**, Vahl.

A small tree with dark grey bark and long pointed glabrescent three-nerved leaves, found usually in shady places and ravines in the outer Himalaya, in Assam, Burma, and parts of the Indian Peninsula. It flowers from June to October and fruits in the cold and hot seasons.

3. **Grewia Hainesiana**, Hole. Vern. *Phalsa, dhaman*, Hind.

A small tree, wild in the sub-Himalayan tract, Siwalik hills, Satpuras, and elsewhere, and cultivated for its edible fruit, propagation being best done by layering.

4. **Grewia elastica,** Royle. Syn. *G. vestita*, Wall. (*G. vestita* may be considered to be a variety of *G. elastica*.) Vern. *Dhaman*, *phalwa*, Hind.

A moderate-sized tree with grey bark, that of branches and young plants with large white blotches; leaves obliquely ovate acuminate, usually much longer than broad. This tree is found chiefly in the sub-Himalayan tract, where it is very common in sal forests, also in Bengal and central India. The wood is tough and elastic, and is used for shoulder-poles, bows, and similar purposes. It is fairly frost-hardy, and in the abnormal drought of 1907–8 in Oudh it was found to be a decidedly drought-hardy species. It coppices freely, and the coppice-shoots are of rapid growth. Measurements recorded by Mr. A. F. Broun in the Dehra Dun forests in 1886 show the following measurements of coppice-shoots of *dhaman* as compared with sal in the same coupes:

Grewia elastica: rate of growth of coppice, Dehra Dun.

	Mean height.				Mean girth.	
Age.	*Grewia.*		Sal.		*Grewia.*	Sal.
years.	ft.	in.	ft.	in.	in.	in.
8	25	0	13	2	12	7·1
8	16	11	16	2	6·2	8·3
9	19	2	16	0	8·4	8·6
9	16	10	13	5	10·1	8·7
10	14	4	17	6	8·8	9·9
10	16	3	11	10	9·4	5·9

Measurements made in 1910 by Mr. C. M. McCrie in coppice coupes at Ramgarh, Gorakhpur, United Provinces, gave the following results in the case of *dhaman* as compared with sal:

Grewia elastica: rate of growth of coppice. Gorakhpur.

	Mean height.		Mean girth.	
Age.	*Grewia.*	Sal.	*Grewia.*	Sal.
years.	ft.	ft.	in.	in.
2	5·2	3	1·4	—
4	9·1	7	2·4	2·0
6	11·5	10·3	3·2	2·9
8	13·6	13	3·8	3·8
10	15·2	15·3	4·3	4·8
12	16·6	17·5	4·7	5·8
14	17·5	19·2	5·0	6·7
16	18·1	20·9	5·3	7·5

Measurements taken for twelve years in the Malowala high forest sample plot on the south of the Siwaliks showed the following mean annual girth increments:

Girth class.	Mean annual girth increment.	Number of measurements.
in.	in.	
0–12	0·56	8
12–24	0·28	10
24–36	0·73	1
36–48	0·52	2

Gamble's specimens showed 5 to 7 rings per inch of radius, corresponding to a mean annual girth increment of 0·9 to 1·26 in.

5. **Grewia tiliaefolia,** Vahl. Vern. *Dhaman*, *phalsa*, Hind.

A moderate-sized tree with large oblique leaves, common in Chota Nagpur, central and southern India. The wood is tough and elastic and is used for shafts, shoulder-poles, and similar purposes. According to Gamble, the growth is about 6 rings per inch of radius, corresponding to a mean annual girth increment of about 1 in. The growth of young coppice-shoots is very rapid. Mr. Gass records measurements in coppice two years old in Madras, in which the height varied from 8 to 15 ft. and the girth from 2 to 7 in., the number of shoots per stool varying from 2 to 12. One-year-old coppice-shoots measured in the Bhandara division, Central Provinces, in 1912–13 had an average height of 8 ft. 2 in.

6. **Grewia Microcos**, Linn. Vern. *Myatya*, Burm.

A moderate-sized tree, sometimes only a shrub, common in Burma often as an undergrowth species, and also found in the Western Ghats, Assam, and Chittagong. It coppices vigorously, an average of 9 shoots per stool being counted in coppice coupes in the Rangoon plains forests. The leaves are much used for cheroot-wrappers in Burma.

4. ECHINOCARPUS, Blume.

Echinocarpus dasycarpus, Benth. Vern. *Gobria, gobre*, Nep.

A large handsome evergreen tree of the eastern Himalaya at 5,000–7,000 ft. Bark greyish brown, rough; wood soft, used for tea-boxes and planking in the Darjeeling neighbourhood. The tree, which is much buttressed, occurs in the middle hill forests of Darjeeling associated with a large number of species, of which the more important are *Quercus lamellosa*, *Q. lineata*, *Q. pachyphylla*, *Castanopsis Hystrix*, *Michelia excelsa*, *Bucklandia populnea*, with laurels, maples, &c. Mr. Manson (Darjeeling working plan, 1893) says it is most common on southern and western aspects, but is also found thriving on slopes facing north-west; it seeds freely, but the seedlings, which have large leafy cotyledons, are rather delicate when very young and require shelter. He adds that the tree comes up well in a sparse growth of weeds on new clearings. Mr. J. W. A. Grieve (Darjeeling working plan, 1912) notes that reproduction is very poor. The rate of growth is given in the working plan at 8–10 rings per inch of radius, corresponding to a mean annual girth increment of 0·63 to 0·78 in.

ORDER XIII. RUTACEAE

This order does not contain any trees of very great importance from a forest point of view, though it includes certain widely cultivated fruit trees, particularly of the genus *Citrus*. As pointed out by Gamble, several species have hard even-grained compact woods well worth trial as substitutes for boxwood. The order contains various shrubs or small trees, often highly aromatic, which are of some importance as species of the undergrowth; of these may be mentioned *Toddalia aculeata*, Pers., a large scandent prickly shrub of the outer Himalaya, Assam, Western Ghats, and Burma; *Skimmia Laureola*, Sieb. and Zucc., a very aromatic undershrub sometimes forming a dense soil-covering in the fir forests of the Himalaya; *Glycosmis pentaphylla*, Correa, a common undergrowth species, often forming a soil-covering in mango topes on the plains of India; *Murraya exotica*, Linn., a handsome shade-bearing

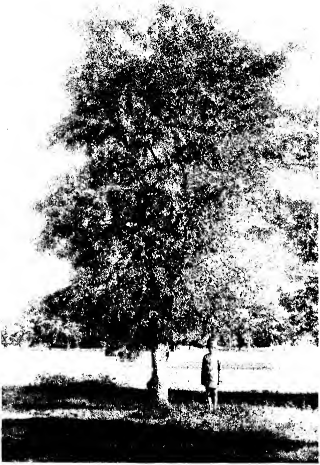

FIG. 68. *Aegle Marmelos*, Dehra Dun, United Provinces.

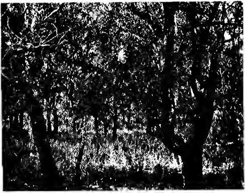

FIG. 69. *Aegle Marmelos* growing gregariously on stiff clay soil, Bahraich, United Provinces.

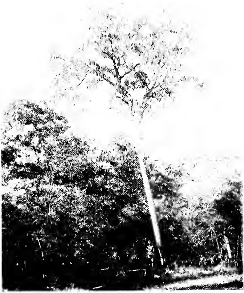

FIG. 70. *Boswellia serrata.*

evergreen shrub or small tree with red berries, found in many parts of India and Burma in shady ravines, and often cultivated for ornament; *M. Koenigii*, Spr., an aromatic shrub or small tree fairly widely distributed in India and extending into Burma, sometimes forming a dense undergrowth in sal or miscellaneous forest; and *Micromelium pubescens*, Bl., a small evergreen tree sometimes, as in the Duars, forming a characteristic under-story in sal forest of a moist type, producing masses of strongly-smelling white flowers towards the end of the cold season. A widely distributed small thorny tree, characteristic of dry open forests, and very common in the dry zone of Upper Burma, is *Limonia acidissima*, Linn., while *Feronia Elephantum*, Correa, is a thorny tree also found in dry open forests and cultivated in many parts of India for the sake of its fruit. By far the most important fruit trees belong to the genus *Citrus*: the cultivated species and varieties include (1) *C. medica*, Linn., (*a*) Var. *medica* proper, the citron, (*b*) Var. *Limonum*, the lemon, (*c*) Var. *acida*, the sour lime, and (*d*) Var. *Limetta*, the sweet lime; (2) *C. Aurantium*, Linn., the orange; (3) *C. decumana*, Linn., the pumelo or shaddock. *C. Hystrix*, DC., vern. *shauknu*, Burm., is a wild species found in Burma and sometimes cultivated in that province. Wild specimens of *C. medica*, and less commonly of *C. Aurantium*, are occasionally met with in the forest, usually in moist shady places, but the position of these trees, along paths and near villages or camping grounds, on old village sites, &c., leads to the conclusion that in most if not all cases they are either escapes from cultivation or have sprung from seed brought by human agency. The species of *Citrus* are cultivated in India in a variety of climates, and do not appear to be exacting in this respect. For a full account of this genus the reader is referred to Brandis's *Forest Flora of North-west and Central India*, 1874, p. 50, while a useful account of the propagation of the cultivated varieties in India, which is carried out by budding, will be found in a paper by W. Burns and H. P. Paranjpye in the *Poona Agricultural College Magazine*, 1913, reproduced in the *Tropical Agriculturist*, vol. xlii, Feb. 1914, p. 117.

AEGLE, Correa.

Aegle Marmelos, Correa. Bael tree. Vern. *Bél*, Hind.; *Bela*, Beng.; *Vilva*, Tam.; *Maredu*, Tel.; *Bila patri*, Kan.; *Ókshit*, Burm. (Fig. 68.)

A small or moderate-sized deciduous tree, reaching a height of 40 ft., the branches armed with straight spines. Trunk often somewhat fluted; bark grey, somewhat corky on the outside. Leaves trifoliate, aromatic. It is one of the sacred trees of India. The wood, which is hard, is used for agricultural and other implements: the chief value of the tree lies in its fruits, which are used medicinally for dysentery and diarrhoea and for making sherbet. The pulp is used to strengthen mortar.

DISTRIBUTION AND HABITAT. Wild in the sub-Himalayan tract, central and southern India, and Burma. Frequently planted all over India and Burma. In its wild state the tree is found as a rule in dry deciduous forests, associated in the sub-Himalayan tract with *Schleichera trijuga*, *Holarrhena antidysenterica*, *Wrightia tomentosa*, *Cassia Fistula*, *Phyllanthus Emblica*. *Bauhinia racemosa*, *Bridelia retusa*, *Odina Wodier*, *Lagerstroemia parviflora*, *Zizy-*

phus Xylopyrus, Acacia Catechu, Anogeissus latifolia, Diospyros tomentosa, and other species. In the Bahraich district a peculiar type of gregarious bael forest is found in patches of varying extent on flat ground with a stiff clay soil. On these patches the bael either grows almost pure or is mixed with *Acacia Catechu* and *Diospyros tomentosa*; the crop is open, the trees are stunted, and there is usually a light crop ol grass on the ground (see Fig. 69). It is probable that the bael has retained possession of these patches of stiff ground to the exclusion of most other species because of its capacity for growing on unfavourable situations, in which it is favoured by its great power of reproduction by root-suckers; in the patches in question the bulk of the young trees can be seen to be root-suckers. Among the drier types of forest in which the tree is found may be mentioned the deciduous forests of South Merwara, where the bael is found associated with *Anogeissus latifolia, Schrebera swietenioides, Dalbergia latifolia, Diospyros Melanoxylon, Cassia Fistula, Randia dumetorum*, and other species.

In its wild state the tree occurs in regions where the absolute maximum shade temperature varies from 105° to over 115° F., the absolute minimum from 30° to 45° F., and the normal rainfall from about 23 to 80 in.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The tree is leafless or nearly so for a short time in the hot season, about April–May. The greenish white very fragrant flowers appear from May to July; they cover the trees and are visited by innumerable bees. The young fruit quickly commences to form, being at first elongated and not round; it becomes full-sized or nearly so by December, and in some cases even shows signs of beginning to ripen then. In northern India it does not actually ripen till April to June of the year after flowering, and some fruits may remain on the tree till the end of July before falling. The fruits are globose, greyish green turning yellow on ripening, 2–4 in. in diameter in the wild state and larger when cultivated, with a hard smooth woody aromatic rind filled with sweet orange-yellow thick mucilaginous pulp in which numerous seeds are embedded. The seeds (Fig. 71, *a*) are oblong, compressed, about 0·3 in. long, with a woolly mucous testa: about 150 weigh 1 oz. Tests carried out at Dehra Dun have shown that the seed does not retain its vitality long, and on the ground is very subject to the attacks of ants, which destroy much of it.

When the hard-rinded fruit falls to the ground, unless broken open by animals it is soon attacked by white ants, while the seeds go bad or are destroyed by insects. The fruits, however, are frequently found broken open by animals, deer breaking them with their hoofs, while pigs and monkeys, and possibly bears and jackals, also eat the pulp: in this way the seed is able to reach the ground before it perishes. Bael seedlings may be seen in the forks of trees and other places to which the seed is taken by the agency of birds.

GERMINATION (Fig. 71, *b–e*). Hypogeous. The whitish radicle emerges from the end of the seed and descends: the short cotyledonary petioles simultaneously elongate, enabling the plumule to emerge and ascend. The fleshy cotyledons remain within the testa below ground.

THE SEEDLING (Fig. 71).

Roots: primary root long, moderately thick, terete, tapering, white at first, becoming yellow: lateral roots few or moderate in number, fibrous,

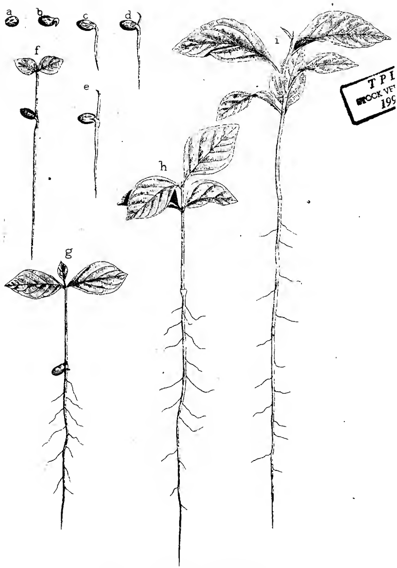

FIG. 71. *Aegle Marmelos.* Seedling × $\frac{5}{8}$.
a, seed ; *b–e*, germination stages ; *f–i*, development of seedling during first season.

T P I
STOCK VE
199

distributed down main root. *Hypocotyl* distinct from the root, **0·1–0·15 in.** long, thick, white, subterranean. *Cotyledons* subterranean: **petiole 0·1 in.** long, curved to side of stem: lamina 0·3–0·35 in. by 0·25–0·3 in., **thick, fleshy,** white, orbicular or broadly elliptical, outer surface rounded, **smooth, inner** flattened in contact. *Stem* erect, terete or slightly compressed, **woody, green,** pubescent; first internode (between cotyledons and first pair **of foliage leaves)** 1·7–2·2 in., subsequent internodes 0·1–0·6 in. long. *Leaves* **simple in first** two seasons, trifoliate leaves appearing later, first pair **opposite, second pair** opposite or sub-opposite, subsequent leaves alternate, **exstipulate, sub-sessile** or with short petioles up to 0·1 in. long, channelled above. **Lamina 1–2·7 in.** by 0·6–1·5 in., ovate or rhomboidal, apex acute, base acute or **slightly decurrent,** crenate or crenate serrate, dark green, glabrous or glabrescent, **with aromatic** glandular dots, venation arcuate, lateral veins 5–8 pairs.

The development of the seedling is very slow. At the end of the first season the stem is ordinarily 2–3 in. high with three to five leaves, and the taproot is 8–10 in. long. By the end of the second season the stem does not ordinarily reach a height of more than 4–6 in. The young plants are apt to die back in frosty localities, but have good power of recovery.

SILVICULTURAL CHARACTERS. The tree is ordinarily found in dry localities unfavourable to the majority of species, and in this respect it may be considered a drought-hardy species. In the abnormal drought of 1907 and 1908 in the forests of Oudh it proved to be decidedly hardy; in the drought of 1899 and 1900 in central India it suffered severely under very unfavourable conditions of soil and climate. Ordinarily it is fairly frost-hardy, but it suffered to some extent in the abnormal frost of 1905 in northern India. Although the tree grows in open forest it is capable of standing a fair amount of shade. It coppices moderately well, and produces root-suckers in abundance. The root-system is superficial, the lateral roots spreading to some distance from the tree.

NATURAL REPRODUCTION. Natural reproduction by seed is not as a rule good, the seed being somewhat perishable and much liable to insect attacks; as mentioned above, its dissemination depends on the agency of animals and birds. Regeneration by root-suckers is at times very plentiful, and this appears to be the chief mode of reproduction.

ARTIFICIAL REPRODUCTION. Seed should be obtained from fruits collected off the trees and not off the ground. The seeds should be washed to remove the pulp, dried for a few days, and, if necessary, coated with red lead to keep off ants. They should be sown fresh about April or May, covered with earth and watered. The seedlings bear transplanting well, but in view of their slow development should not be transplanted until the rains of the second season or even the third season in the case of backward plants.

RATE OF GROWTH. The rate of growth is slow. Measurements by Mr. C. M. McCrie in Gorakhpur, United Provinces, of coppice-shoots nine and eleven years old showed an average height of 8 ft. and 9 ft. 6 in., and an average girth of 2·2 in. and 2·4 in. respectively, while sal coppice in the same coupes showed an average height of 15 ft. 7 in. and 19 ft. 2 in. respectively.

ORDER XIV. SIMARUBACEAE

This is a small and comparatively unimportant order so far as Indian forestry is concerned.

AILANTHUS, Desf.

Species 1. *A. excelsa*, Roxb.; 2. *A. malabarica*, DC.; 3. *A. glandulosa*, Desf.

1. **Ailanthus excelsa**, Roxb. Vern. *Maharukh*, Hind.; *Arua*, Rajputana; *Maha nim*, Uriya; *Pedda manu*, Tel.

A large deciduous tree. Bark light grey and smooth in young trees, with large conspicuous leaf-scars, rough, granular, and greyish brown in older ones. Leaves pinnately compound, up to 3 ft. long with 8–14 pairs of leaflets. In seedlings and saplings imparipinnate leaves are the rule for the first three or four years, after which the terminal leaflet becomes reduced in size, or is represented by a mere prolongation of the rachis, and finally the typical abruptly paripinnate leaves are formed about the fourth or fifth season. The wood, which is soft and white, is used for packing-cases, and is reported to make good match splints.

Distribution and habitat. Indigenous in the Indian Peninsula, and often planted in different parts of India. It is found in mixed deciduous forest and, in the Central Provinces, also in sal forest; it is common round villages.

Leaf-shedding, flowering, and fruiting. The panicles of small yellowish flowers appear in February–March, and the fruits ripen in May–June. The fruit (Fig. 72, *a*) is a red one-seeded samara, 2–3 in. long by 0·5–0·6 in. wide, prominently veined, acute at both ends and twisted at the base; about 260 to 300 weigh 1 oz. The fruit being winged is adapted for dissemination by wind. A considerable proportion of the seed loses its vitality if kept for one year.

Germination (Fig. 72, *b–e*). Epigeous. The radicle and plumule emerge from the cell and break through the winged covering, the cotyledons being carried up and the testa usually left inside the fruit. The hypocotyl arches somewhat at first, soon straightening: there is a decided kink at its base owing to the effort of the seedling to escape from the cell in which the seed is enclosed.

The seedling (Fig. 72).

Roots: primary root moderately long, terete, tapering: lateral roots moderate in number and length, fibrous. *Hypocotyl* distinct from the root, with a well-marked bend at the junction, 1–1·5 in. long, terete, tapering upwards, white turning green, minutely tomentose. *Cotyledons*: petiole 0·1 in. long or less, flattened above, tomentose: lamina 0·6–0·7 in. by 0·4–0·5 in., foliaceous, somewhat fleshy, elliptical ovate, apex rounded, base rounded or sub-truncate, entire, green, glabrous, venation pinnate reticulate. *Stem* erect, terete, green, minutely tomentose. *Leaves*, first few sub-opposite, subsequent leaves alternate, earlier leaves trifoliate, subsequent leaves imparipinnate with number of leaflets gradually increasing, paripinnate leaves forming about the fourth or fifth season. Stipules absent. Common petiole of trifoliate leaves 0·3–0·5 in. long, tomentose. Leaflets opposite or sub-opposite, shortly petiolate

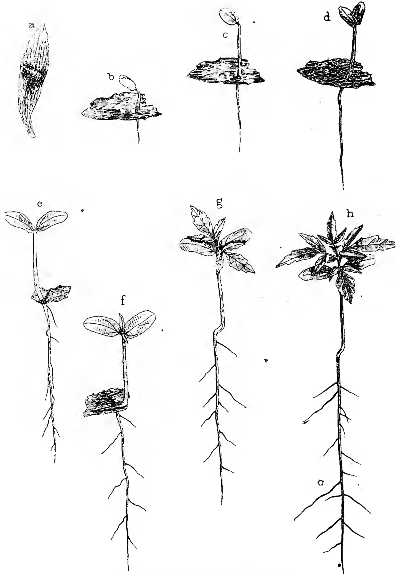

FIG. 72. *Ailanthus excelsa*. Seedling $\times \frac{3}{8}$.
a fruit ; *b–e*, germination stages ; *f–h*, early development of seedling.

or sub-sessile, pubescent or glabrescent; terminal leaflet 0·7–1·2 in. by 0·3–0·6 in., ovate, acute or acuminate, coarsely serrate or nearly lobed; lateral leaflets 0·4–0·8 in. by 0·2–0·4 in., obliquely ovate lanceolate, acute or acuminate, coarsely serrate.

The cotyledons usually persist for about 2–3 months, when they turn yellow and fall. By the end of the first season the seedlings reach a height of 2–9 in., according to whether they have been watered and weeded or not: the more vigorous plants then have 7 or 8 trifoliate leaves, followed by a few 5-foliate ones. From the second season, if the plants are well weeded, growth is rapid; in experimental sowings at Dehra Dun the following dimensions were reached:

End of second season—height 2 ft. or more.
End of third season—height 8 ft. or more.
End of fourth season—height 14 ft., girth 12½ in.

Where weeding is not carried out they seldom reach a height of 1 ft. by the end of the second season. In northern India the seedlings drop their leaves about February, and new shoots appear at the end of February or in March. Seedlings are much subject to insect attacks in their early stages; they are sensitive to frost, and are also apt to die off in dry weather or where the drainage is bad. Heavy weed-growth prevents their development and causes high mortality.

Silvicultural characters. The silvicultural characters of this tree have not yet been fully studied. It coppices well and produces root-suckers. It is said to be easily broken by wind.

Natural reproduction. As a rule natural reproduction in the forest is not good. This is probably due to the sensitiveness of the seedling, to its intolerance of heavy weed-growth, and to the fact that the seed requires bare ground for successful germination. Experiments at Dehra Dun have shown that under natural conditions germination takes place early in the first rainy season after the fall of the seed.

Artificial reproduction. Plants can be raised easily from seed or from cuttings. Large cuttings strike readily, and root-cuttings may also be used to produce shoots. For artificial propagation by seed a light porous soil is necessary. The seed should be sown in May or June in well-raised seed-beds in drills about 9 in. apart, water being given regularly but sparingly, as the seedlings will not stand an excess of it. Under favourable conditions germination takes place 1–2 weeks after sowing. Regular weeding should be carried out, and in the cold season the plants should be protected if frost is to be feared. The seedlings will be ready to transplant during the rains of the second season; they stand the operation well. At Dehra Dun direct sowings, both irrigated and unirrigated, have succeeded well, but it was found that thorough weeding was essential to success.

Rate of growth. The rate of growth is known to be rapid, but no statistics are available.

2. **Ailanthus malabarica,** DC. Vern. *Dhup*, Kan.; *Peru*, Tam.

A large ornamental deciduous tree with a tall cylindrical trunk and grey bark with a thin corky layer on the outside, yellow mottled and fibrous inside. The tree occurs in evergreen forests of the Western Ghats, from the Konkan southwards and on the eastern slopes of the Pegu Yoma in **Burma**; it is often planted for ornament in southern India. It flowers in **February–March**, and the fruit, a reddish brown samara, 2·5–3 in. long, ripens in **April–May**. The wood, which is soft and white, is not used; but the tree yields a fragrant resin used as incense and in native medicine.

3. **Ailanthus glandulosa**, Desf.

A large tree indigenous in China and sometimes planted in India. It has been tried in the North-West Frontier Province with some success; experience there has shown that it can be transplanted easily and requires little water, while it grows fast, produces fertile seed in abundance at an early age, and spreads rapidly by root-suckers.

ORDER XV. BURSERACEAE

An order containing a few trees with useful timber and others important in Indian forestry owing to their abundance or wide distribution. Most of the trees are resinous. Among trees of moist regions may be mentioned the various species of *Canarium*, all large resinous trees. *Bursera serrata*, Colebr. (vern. *Najor*, Ass.; *Kandior*, Kol; *Armu*, Santal; *Thadi*, Burm.) is a moderate-sized to large tree, evergreen or nearly so, found commonly along streams, in ravines, or on rocky ground in cool situations, in Assam, Chittagong, Chota Nagpur, Orissa, northern Circars, and Burma; rare in the Central Provinces. It stands moderate shade in youth.

Genera 1. Boswellia, Roxb.; 2. Garuga, Roxb.

1. BOSWELLIA, Roxb.

Boswellia serrata, Roxb. Syn. *B. thurifera*, Colebr.; *B. glabra*, Roxb. Vern. *Salai*, *saler*, Hind.; *Anduga*, Tel. (Fig. 70.)

A moderate-sized to large deciduous, usually gregarious, tree with light spreading crown, somewhat drooping branches and compound imparipinnate leaves 12–18 in. long; bark greenish grey to yellow or reddish, fairly thick, smooth, exfoliating in thin papery flakes, resinous inside. The tree ordinarily reaches a height of 30–50 ft., and a girth of 4–6 ft. Wood moderately hard, whitish, resinous, with a small brown heartwood, used for rough planking, boxes, well-construction, &c., and for match manufacture. A fragrant gum-resin exudes from wounds in the bark, and is used as incense and in medicine: it shows promise of furnishing, on distillation, rosin and turpentine of some economic value. The branches are lopped for buffalo fodder in Ajmer. The tree is a most useful one for clothing dry, hot, barren hills.

Distribution and habitat. The tree is common and usually gregarious on dry hills throughout the greater part of India; it does not occur in Assam or Burma. In northern India it is found on the southern slopes of the Siwalik hills flanking the Himalaya, on dry sandstone ridges associated with *Zizyphus Xylopyrus*, *Odina Wodier*, *Anogeissus latifolia*, *Acacia Catechu*, *Buchanania latifolia*, *Nyctanthes Arbor-tristis*, and other species. It is common on the dry hills of Chota Nagpur. In Rajputana it occupies the drier ridges of hills on metamorphic rocks, chiefly gneiss and schists, either pure or mixed with *Odina Wodier*, *Sterculia urens*, and a few other species. In the drier parts of

Bombay, the Central Provinces, Berar, and the Peninsula generally it occupies the hotter slopes and ridges of hills, usually on trap and sometimes on gneiss and schist, with *Sterculia urens*, *Anogeissus latifolia*, *Odina Wodier*, *Acacia Catechu*, and a few other species, and sometimes *Hardwickia binata* or stunted teak. On the poorest and shallowest soil. or where the ground is ferruginous, it is found pure or nearly so ; here it is able to thrive and to reach fair dimensions where every other species, with the possible exception of *Sterculia urens*, remains stunted. It always forms comparatively open forests.

In its natural habitat the absolute maximum shade temperature varies from 110° to 120° F., the absolute minimum from 30° to 45° F., and the normal rainfall from 20 to 50 in.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The leaves turn yellowish to light brown in December, and commence to fall in quantity, the curled up leaflets covering the ground and crackling under foot. At this season the trees are recognizable at a distance by the light brown colour of their foliage. By the end of January to the beginning of March the trees are leafless, and remain so till the new leaves appear in May or June. The racemes of rather small white or pale pink fragrant flowers appear at the ends of the branches from the end of January to March or April, when the tree is leafless or nearly so, and the fruits ripen in May–June. The fruit is a 3-gonous drupe with a woody pericarp, splitting into three valves and containing three hard pyrenes, each surrounded by a membranous wing.

SILVICULTURAL CHARACTERS. The *salai* is a strong light-demander. It has great vitality ; in order to kill trees by girdling, in the interests of more valuable species, the cut has to be made both deep and broad. It stands fire better than almost any other species in the dry tracts which it frequents. In the abnormal drought of 1899–1900 in the Indian Peninsula it suffered only slightly ; it is, however, somewhat frost-tender. It is not readily browsed by cattle. Porcupines do much damage to *salai* trees in certain localities by eating off the bark and sometimes girdling and killing the trees. Pigs have a great partiality for the seedlings, which they grub up. Cases of damage by gales have been recorded, the trees being uprooted and thrown down. The *salai* produces root-suckers, but its power of producing coppice- and pollard-shoots is variable. In Bhandara, Central Provinces, Mr. Haines notes that it never fails to coppice if cut in the dry weather and freed from overhanging cover. In Jubbulpur several instances are recorded of *salai* under 3 ft. in girth coppiced ten years previously having produced vigorous shoots which remained in a healthy condition up to date. In Ajmer it usually coppices well, while in the drier parts of Berar coppicing is reported to have given very fair results. On the other hand it is reported that the tree cannot be relied on for coppice reproduction in Nimar. A series of experiments in Narsinghpur, in which pollarding was carried out as well as coppicing both flush with the ground and at a height of 1 to 2 ft., resulted in almost complete failure. Experiments in Saugor showed that *salai* in that district neither coppices nor pollards well : it was found that in the first year or two pollard-shoots grew better than coppice, but many died off in the second and third years, and eventually the percentage of success was practically the same in either case. though the coppice-shoots tended to become more vigorous than the pollard-shoots. The precise reason of this variation in coppicing power has not yet been ascertained. It has been suggested that it may be due to geological formation: thus in Ajmer and Bhandara, where the tree coppices well, the rock is mainly gneiss, schist, and quartzite, while on most of the trap areas it coppices poorly.

NATURAL REPRODUCTION. Natural reproduction is usually good, even on the poorest ground; some of this is due to root-suckers, but the tree also reproduces well from seed.

ARTIFICIAL REPRODUCTION. The *salai* reproduces well from large cuttings; these should be planted in the rainy season when the soil is damp. Attempts to raise it artificially in Berar by line sowings with the aid of field crops resulted in failure, owing to the fact that the seedlings were practically all rooted up by pigs. As regards the capacity of the tree for growing from cuttings, Mr. C. M. McCrie informed me of a case which occurred in the Saugor district, Central Provinces, in a year of severe drought. when many kinds of trees were dying for want of moisture: some posts of *salai* were stuck in a row in the ground to form a barrier to prevent the passage of cattle, and in spite of the intense drought many of the posts sprouted and developed flourishing shoots.

RATE OF GROWTH. Statistics of the rate of growth of trees are not available. Where coppice-shoots are produced they grow rapidly. In Bhandara, shoots reached a height of 6 ft. 11 in. in one year, and 20 ft. in three years. In Nimar, measurements of one-year-old coppice-shoots on very poor shallow trap soil in seven different plots showed a maximum and minimum height of 7 ft. 2 in. and 2 ft. respectively, and an average height varying from 4 ft. to 6 ft. 1 in.

2. GARUGA, Roxb.

Garuga pinnata, Roxb. Vern. *Kharpat, kaikar*, Hind.; *Kudak*, Mar.; *Garuga, gargu*, Tel.; *Chinyôk*, Burm. (Fig. 73.)

A large deciduous tree with compound imparipinnate leaves, which are often covered with red galls. Bark thick, soft, greyish brown, exfoliating in large irregular hard flakes, red inside. Sapwood large and white; heartwood reddish brown, moderately hard. Wood not very durable, used for inferior building and other purposes. Although its economic value is not great, the tree is of interest as an accessory species owing to its wide distribution in important types of forest.

DISTRIBUTION AND HABITAT. The tree is widely distributed throughout India and Burma, chiefly in mixed deciduous forests; it is a common associate of teak and sal. It is a typically sporadic species, and does not occur gregariously, except in patches of limited extent. In the miscellaneous hilly forests of drier regions it is most prevalent on cool aspects and in ravines, but elsewhere it is not particular as to aspect. In Burma it is common in the lower mixed forests of the plains as well as in the upper mixed forests.

In its natural habitat the absolute maximum shade temperature ordinarily varies from 105° to 115° F., the absolute minimum from 30° to 55° F., and the normal rainfall from 40 to 100 in. or more.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The tree is ordinarily leafless for several months during the dry season, but the time of leaf-fall varies

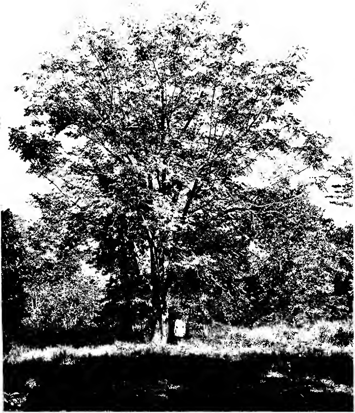

FIG. 73. *Garuga pinnata*, Dehra Dun, United Provinces.

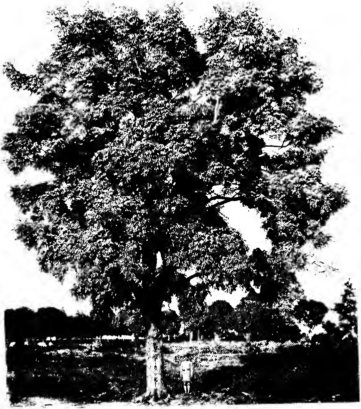

FIG. 74. *Cedrela Toona*, Dehra Dun, United Provinces.

greatly. Before falling the leaves turn red, the leaflets falling separately and the rachis following: in northern India they commence to fall during November, but many trees remain in full leaf, particularly in cool, moist localities, till December or even January. The tree ordinarily remains leafless until April or May, but in moist localities the new leaves may appear as early as March. The flower-buds appear at the ends of the bare branches in February or March, and in March or April the leafless trees are conspicuous with feathery masses of greenish white flowers. The fruits develop very quickly, the round green drupes commencing to form before all the flowers have fallen. In northern India the fruits become full sized by June, but are not ripe until July and August, and do not all fall until September. The fruit is a globose drupe, yellowish green when ripe, containing 2–4 extremely hard stones about 0·3 in. in diameter.

GERMINATION. Epigeous. The hard stone splits in two, the radicle pushes its way downwards and the 5-partite cotyledons emerge shortly afterwards; the fragments of the stone remain in or on the ground.

THE SEEDLING. During the first season the seedling develops fairly rapidly after germination, reaching under natural conditions a height of 4–6 in. or more by the end of the season. During the second and subsequent years growth is rapid even under natural conditions where no watering or weeding is done, the plants reaching a height of 1½ to 3 ft. by the end of the second season, and a maximum height of over 10 ft. and a girth of 5 in. by the end of the third season. The seedlings do not appear to mind a moderate growth of grass and weeds, but if suppressed by shade they show poor development. They are frost-tender, but have great power of recovery. Growth ceases about October and new growth starts in March–April. The leaves of seedlings fall from December to March.

SILVICULTURAL CHARACTERS. *Garuga pinnata* is a strong light-demander, becoming readily suppressed under shade. It is frost-tender both in the seedling stage and later, but has good power of recovery; it suffered severely in the abnormal frost of 1905 in northern India. It is also sensitive to drought, and was badly affected in the severe drought of 1899 and 1900 in the Indian Peninsula. It is one of the most fire-resisting species in the localities where it grows, its thick moist bark and recuperative power standing it in good stead. It coppices well and produces root-suckers.

NATURAL REPRODUCTION. The seeds are to some extent distributed by birds, which eat the acid flesh of the fruits and scatter the stones to a distance from the tree. Many fruits, however, fall to the ground round the trees. They quickly turn black, emitting a strong odour resembling freshly cut teak-wood and blackening the ground around them. The fleshy portion of the fruit decays or shrivels up and is washed away by rain or eaten by white ants, leaving the stones exposed. When the fruits fall the rainy season is at its height, and under natural conditions the seed does not ordinarily germinate that year. The stones lie on the ground, many becoming half buried with the action of the rain, and thus they remain through the succeeding cold and hot seasons. At the commencement of the next rainy season germination commences, and seedlings may often be found in abundance in the neighbourhood of seed-bearers; they are easily recognized from the peculiar deeply cleft cotyledons with five narrow lobes. Some of the seed lies dormant over two dry seasons, and does not germinate until the beginning of the second rainy season after the fall of the fruit. Two essential factors for successful reproduction are abundance of light and freedom from overhead suppression. The seedlings appear to have no difficulty in making their way through a moderate growth of grass and low weed growth, such as they are almost bound to encounter, since the seed has no opportunity of germinating on new ground, but lies ungerminated for one and sometimes two years.

ARTIFICIAL REPRODUCTION. The ripe fruits should be collected about July, placed in drills in seed-beds, very lightly covered with earth, and regularly watered during the dry season. Most of the seed will germinate early in the rains of the following year, though some may germinate sooner; the seedlings can be transplanted without difficulty about six weeks to two months after germination, when they are about 4 or 5 in. high. Transplanting, however, checks the growth, and better development is obtained by direct sowing. As in the case of *Boswellia serrata*, large cuttings of *Garuga pinnata* strike readily. A few years ago young trees of various species planted in the Lachiwala camping ground near Dehra Dun were surrounded by posts of *Garuga* about 6 ft. high and 1 ft. in girth, to which barbed wire was nailed to keep off cattle; some of the posts sprouted and developed into flourishing trees, which eventually suppressed the trees they were intended to protect.

RATE OF GROWTH. The rate of growth is fast, particularly in the case of trees up to middle age. Coppice-shoots of *Garuga* as a rule grow more rapidly than those of any species associated with it. In the Siwaliks, coppice-shoots were measured which had reached a height of 35 ft. in ten years, while coppice measurements in Gorakhpur, United Provinces, showed an average height of 50 ft. and a girth of 1 ft. 10 in. in sixteen years, sal having reached an average height of 18 ft. 3 in. and a girth of 6 in. in the same coupe. In more or less dense crops the girth development is comparatively slow, owing to the light-demanding character of the tree.

ORDER XVI. MELIACEAE

This is an important order in Indian forestry, containing as it does several trees with useful and valuable timbers; the wood is most commonly reddish and mahogany-like.

Genera 1. AZADIRACHTA, Adr. Juss.; 2. MELIA, Linn.; 3. CARAPA, Aublet; 4. SOYMIDA, Adr. Juss.; 5. CHICKRASSIA, Adr. Juss.; 6. CEDRELA, Linn.; 7. CHLOROXYLON, DC.; 8. DYSOXYLUM, Blume; 9. SANDORICUM, Cav.; 10. AMOORA, Roxb.; 11. SWIETENIA, Linn.

1. AZADIRACHTA, Adr. Juss.

Azadirachta indica, A. Juss. Syn. *Melia indica*, Brandis; *M. Azadirachta*, Linn. Neem, margosa. Vern. *Nim*, Hind.; *Yepa*, Tel.; *Tamaka*, Burm.

A moderate-sized to large, usually evergreen tree, with a fairly dense rounded crown and glabrous imparipinnate leaves; bark moderately thick, furrowed longitudinally and obliquely, dark grey, reddish brown inside. The heartwood is red, hard, and durable, and is used for house-building, furniture, and many other purposes; the bark, gum, leaves, and flowers are all used in medicine, while the seeds yield an oil used in medicine and for burning.

Distribution and habitat. The natural habitat of the tree in India is somewhat difficult to determine. It is common in the open scrub forests of the dry zone of Burma, and is found apparently wild on the Siwalik hills; Gamble says that if wild anywhere in India it is probably so in the forests of the Carnatic and parts of the Deccan. In the Saharanpur Siwaliks I have found it in some quantity on the inner ridges in places where it is difficult to believe it could have spread from cultivated trees. It is cultivated all over India and Burma, more especially in the drier parts of the country, and has evidently become wild in many localities as an escape from cultivation. It is a very useful roadside or avenue tree in dry and moderately dry climates, thriving as a rule where the normal rainfall varies from 18 to 45 in., and where the maximum shade temperature may be as much as 120° F., though it will not stand excessive cold. It will grow on most kinds of soil, does well on black cotton soil, and does not do badly even on clay. It thrives better than most other species on dry stony shallow soil with a waterless subsoil, or in places where there is a hard calcareous or clay pan not far from the surface. It will not grow well on land liable to inundation.

Leaf-shedding, flowering, and fruiting. Only in dry localities does the tree become almost leafless for a brief period; otherwise it is always evergreen, the new leaves appearing in March–April before the old ones have all fallen. The panicles of small white flowers, smelling of honey, appear from March to May, and the fruit ripens from June to August. The fruit (Fig. 75, *a*) is a smooth ellipsoidal drupe 0·5–0·7 in. long, greenish yellow when ripe, one-celled and one-seeded or sometimes two-seeded. The seed does not retain its vitality long.

Germination (Fig. 75, *b*–*f*). Epigeous. The true testa of the seed is a brown papery covering inside the cartilaginous putamen of the drupe. The radicle emerges from the end of the seed and the hypocotyl arches, withdrawing the cotyledons from the two coverings, and in straightening raising them above ground; the two coverings are either left in the ground or carried up over the cotyledons, from which they eventually drop to the ground.

The seedling (Fig. 75).

Roots: primary root moderately long, terete, tapering: lateral roots moderate in number and length, fibrous, distributed down main root. *Hypocotyl* distinct from root, 0·8–1·7 in. long, terete, cylindrical or tapering slightly upwards, white soon turning green, glabrous. *Cotyledons* sub-sessile or with petioles up to 0·05 in. long: lamina 0·4–0·5 in. by 2·5–3 in., thick, fleshy, elliptical, apex rounded, base sagittate, outer surface convex, inner flattened in contact, entire, green, glabrous. *Stem* erect, terete or slightly compressed, glabrous; internodes 0·2–1·3 in. long, the first (above the cotyledons) usually longer than those succeeding. *Leaves*, first pair usually opposite, subsequent leaves opposite to alternate, first few trifoliate, later leaves 5-foliate. Stipules absent. Rachis 0·3–1 in. long, glabrous, channelled above. Lateral leaflets opposite, terminal leaflet somewhat larger than lateral ones: leaflets sessile or sub-sessile, 0·8–1·3 in. by 0·3–0·6 in., ovate lanceolate, acuminate, unequally serrate, often more or less 3-lobed.

During the first season the seedling shows moderate development, ordinarily reaching a height of 4–8 in. by the end of the year. Experiments carried out at Dehra Dun have shown that development is much retarded by weed-growth, and that regular weeding greatly stimulates the growth and vigour of the seedling. In these experiments it was found that if weeded and moderately irrigated, seedlings reached a height of 2 to 4½ ft. by the end of the second season, and a height of 5 to 7 ft. by the end of the third season: if weeded and not irrigated they reached a height of 1 ft. 8 in. to 3 ft. 3 in. by the end of the second season. Where weeding was not carried out the seedlings showed very poor development, and were eventually killed by suppression and frost. In northern India the growth of the seedlings ceases about October–November, and the new shoots appear about March. The seedlings are very frost-tender, and when killed down to ground-level have little power of recovery; they are intolerant of an excess of moisture in the soil, the taproot tending to rot.

SILVICULTURAL CHARACTERS. The neem is a light-demander, but has great capacity for pushing its way through thorny scrub in youth; in this respect it resembles *Bombax malabaricum*. It is very frost-tender, especially in the seedling and sapling stages. Its capacity for thriving on poor dry ground and its intolerance of an excess of moisture in the soil have already been alluded to. It coppices well and produces root-suckers, especially in dry localities. It is not readily browsed by cattle and goats; it is, however, recognized as fodder suitable for camels. In some localities porcupines damage and sometimes girdle and kill the trees by gnawing off the bark round the base.

NATURAL REPRODUCTION. Under natural conditions the seed ordinarily reaches the ground in the rainy season, and germination takes place in one to two weeks. Although the tree is believed not to be indigenous in India except to a very limited extent it often reproduces naturally with tolerable freedom: in this it is aided by its capacity for establishing itself under the protection of thorny bushes and its hardiness on dry poor soil, provided it is not subjected to frost.

ARTIFICIAL REPRODUCTION. Although the neem can be easily raised in the nursery and transplanted, for forest purposes direct sowings have proved more successful than transplanting. Care is necessary in the collection of the seed: it should be collected off the trees about July when thoroughly ripe, and should be sown as soon after collection as possible. It is advantageous to cover the seed lightly with earth, since seed germinating on the surface of the ground is liable to have the radicle eaten off by insects.

For raising transplants the seed sown in the nursery should be lightly covered with earth and sparingly watered, the soil being kept loose to prevent caking. The seedlings will be fit to transplant during the first rains, when they are 3 to 4 in. high, the taproot then being about 6 in. long: if larger seedlings are required they may be kept another year in the nursery and transplanted early in the rains of the second season, the plants being protected in winter by screens in frosty localities. Transplanting may be carried out successfully after pruning down the stem and roots: this system has been adopted with success in the afforestation of Talankheri hill, Nagpur.

The neem has been employed for afforestation purposes in dry situations in various localities, as a rule with great success. Different methods of direct sowing have been practised. The following examples may be cited:

1. In the *Indian Forester*, vol. i, p. 201, an account is given of the raising of neem by sowings along with *arhar* on the highest and driest site available in Lucknow. Seed was sown in July 1872 on ground which had been twice ploughed up. No watering was done, but the seedlings were kept free of weeds. In May 1875 the plants were 7 to 8 ft. high, the growth being equal to or better than that of transplants which had been carefully watered and tended.

2. Similar sowings of neem and *arhar* were made in Bahraich forest division, Oudh, in June 1872, no watering being done. Most of the *arhar* died in the first winter, chiefly from frost, though it saved the neem seedlings. Next year the *arhar* recovered somewhat, but died out in the latter part of the second year. The neem suffered much from frost in the second and third winters, but in spite of this the sowings proved very successful, the plants being from 1 to 12 ft. in height when three years old. It was noticed that the plants succeeded best where they were sheltered from the north by existing trees.

3. In the *Indian Forester*, vol. xxxiii, p. 177, Mr. L. S. Osmaston describes experimental sowings of neem on poor ground on trap formation in the Nasik district, Bombay, where the rainfall is about 24 in. Owing to the collection of seed which was largely unripe the success was not as great as it might have been, but such as it was it was greatest in the case of sowings on large mounds 2½ ft. high, 2 ft. in diameter at the top, and 7 ft. in diameter at the base; here the plants reached a height of 3 ft. after sixteen months from the date of sowing. It was found that one man could prepare five to seven such mounds in a day.

4. In the *Indian Forester*, vol. xxxiii, p. 265, the same writer describes experiments in the raising of neem and other trees by sowings in combination with the cultivation of field crops (sesamum, cotton, and the lesser hemp) in a dry region of the Bombay Deccan with a rainfall of slightly under 20 in.; this form of raising plantations he considers from experience to be the only successful one in the dry region in question. Operations were conducted where possible by the aid of lessees, a two years' lease being given out and the sowing both of the field crops and of the tree seeds being done, after ploughing and harrowing, with special sowing implements in use in the Deccan. Under one method the lessee cultivated field crops in the first year, and sowed tree seeds as well as field crops during the second year: the sown lines were 1 ft. apart, three lines of field crops to one line of tree seeds, so that the latter were 4 ft. apart. The lessee weeded the lines of tree seedlings twice during the first rains. Under a second method the tree seeds as well as the field crops were sown in strips 4 ft. broad (in four lines 1 ft. apart), alternating with strips of field crops 8 ft. broad; the lessee weeded the strips of tree seedlings, sowed up blanks in them during the second rains, and continued cultivating field crops between the strips of tree seedlings during the second season. The success of these sowings must depend largely on the rainfall, and provided this is not too scanty they are decidedly promising, the neem reaching a maximum height and girth of 16 ft. and 1 ft. 5 in. by the end of the fourth season.

In the case of departmental sowings the cost of formation up to that time, including collection of seed, ploughing, sowing, and weeding, but not including supervision, amounted to Rs. 28-11-0 per acre, against which receipts from the produce of field crops amounted to Rs. 32, leaving a profit of Rs. 3-5-0 per acre. Thus the raising of plantations with field crops by the agency of lessees should be possible at comparatively small cost, after allowing a reasonable profit to the cultivator.

5. In the Bellary district of Madras great success has been attained by sowing neem seeds on mounds in black cotton soil. This soil is troublesome owing to its tendency to develop cracks in dry weather, and special measures are necessary to counteract this. In the *Indian Forester*, vol. xxxvii, p. 659, Forest Ranger S. Thumboo Naidu describes two methods of carrying out neem sowings on this soil in Bellary. Under one method seed was sown on mounds of dimensions 12 ft. by 4 ft. by 1½ ft., prepared in rows 9 ft. apart: the cracks which developed subsequently were filled in with earth. A year after sowing the plants had reached a maximum height of 4½ ft. The total cost of formation, including the preparation of the mounds, sowing seed, and filling cracks, was Rs. 7-2-0 per acre. Figures given in the circle reports indicate that these mound sowings can be carried out at a cost of little more than Rs. 4 per acre. A second method tried was to sow in furrows 6 ft. apart in land previously ploughed with iron ploughs and levelled. The sides of the furrows were subsequently kept loosened to prevent cracks, and existing cracks were filled in with loose earth; this method succeeded only partially, but in successful places the plants numbered as much as 1,500 per acre, and had a height of 2 to 5 ft. after one year. The total cost of formation in this case amounted to Rs. 13 per acre. Broadcast sowings on land ploughed with iron ploughs gave very poor results.

6. In Ajmer success has been attained by dibbling neem seed under *Euphorbia* bushes.

7. In Berar the neem is grown along with the babul (*Acacia arabica*) in line sowings with the aid of field crops; in this case the neem is regarded more as a secondary species, as pure babul has been found to be much subject to insect attacks. After various trials the following system has been finally adopted: The year's coupe is sold by public auction to a lessee who is required to clear-fell the area, grub out the stumps and plough the land, after which he is permitted to cultivate the area with any field crops he pleases for two years. In the third year, at the commencement of the monsoon, a mixture of 75 per cent. of babul seed and 25 per cent. of neem seed is sown in lines 12 ft. apart, the lessee sowing lines of cotton in between. The babul and neem plants are thereafter kept regularly weeded and thinned, blanks being filled up in the year following the sowing. Cultivation of cotton between the lines is continued as long as is practicable, and cattle, excluding buffaloes, goats, and sheep, are admitted to graze at the rate of one head per acre when the crops are off the ground, this being found beneficial in keeping down grass.

A series of experiments at Dehra Dun has demonstrated the necessity for keeping neem seedlings free from grass and weeds; these not only retard development and cause many casualties, but also intensify damage by frost. Thorough weeding without watering was found to have results almost, if not quite, equal to those attained by the more expensive process of irrigation with weeding: the loosening of the soil to prevent caking and promote soil-aeration was also found to be most beneficial. In either case direct sowing was found to give better results than transplanting nursery-raised plants.

Rate of growth. It is sometimes held that the annual rings of neem are not visible or cannot be relied on. Mr. A. W. Lushington, writing in the *Indian Forester*, vol. xxiii, p. 123, states that he examined the rings on some trees felled in a plantation fourteen years old, and found fourteen clearly marked annual rings, with other spurious rings which did not go round but merged into the annual rings: they seldom went more than a quarter of the way round. In counting rings on neem stumps, care is necessary to avoid these spurious rings. As mentioned above, the rate of development of young plants after the first season is fairly rapid. As a rule trees put on a mean annual girth increment of 0·9 to 1·2 in., though more rapid growth is attained under favourable conditions. Mr. F. Gleadow[1] records a tree sixteen years old with a girth of 4 ft. 4 in. in the Changa Manga irrigated plantation, Punjab.

A small plantation at Motipur in the Bahraich district, United Provinces, formed in 1872 by sowings with field crops, was measured by Mr. M. W. Clifford early in 1916, when forty-four years of age; as a result of measurements of 32 trees the average girth and height were found to be 2 ft. 8 in. and 35 ft. respectively. The plantation had not been regularly tended, and all the trees were more or less damaged by man and cattle and were rather badly grown, otherwise the growth would doubtless have been faster.

2. MELIA, Linn.

Species 1. *M. Azedarach*, Linn.; 2. *M. composita*, Willd.

1. Melia Azedarach, Linn. Persian lilac, bead tree. Vern. *Bakain, drek*, Hind.; *Yerri vepa*, Tel.; *Vembu*, Tam.; *Pejri*, Mar.

A moderate-sized deciduous tree with a short bole and a spreading crown, bipinnate or tripinnate leaves, and a dark grey bark with shallow longitudinal furrows. The tree sometimes reaches fairly large dimensions: Mr. A. E. Wild records one 8 ft. 8 in. in girth at Sataura in Hazara. The wood is used for furniture, agricultural implements, cigar-boxes, &c.; the fruit-stones are commonly used as beads.

Distribution and habitat. Doubtfully indigenous except possibly in Baluchistan and Kashmir. Commonly cultivated for the sake of its handsome flowers and as a roadside tree in various parts of India and Burma, growing in the Himalaya up to 6,000 ft. and even higher. In the Changa Manga plantation near Lahore it is perhaps the commonest species after sissoo and mulberry.

Leaf-shedding, flowering, and fruiting. The tree is usually leafless from about December to March or April. The handsome panicles of lilac flowers appear from March to May. The fruits ripen in the cold season, but remain on the tree in yellow clusters during the flowering season, and some may be still on the trees in July. The fruit (Fig. 76, *a*) is a drupe 0·5–0·6 in. long, nearly globose, yellow when ripe, smooth at first, afterwards wrinkled, the flesh rather dry: endocarp bony, very hard, usually five-celled and five-seeded. Tests have shown that the seed retains its vitality unimpaired for at least a year: in this it differs from the neem (*Azadirachta indica*). Indeed in one case, seed kept for one year showed a fertility nearly four times as great as fresh seed from the same sample.

---

[1] Ind. Forester xxv (1899), p. 245

If the fruits are sown in nursery beds and watered, germination usually takes place within two or three weeks. Under natural conditions, however, the fruits fall to the ground shortly before or during the rains, and as a rule lie dormant until the following year, germinating during the rains or sometimes earlier in the season if there is much rain.

GERMINATION (Fig. 76, *b–g*). Epigeous. From each fruit-stone one to four seedlings may emerge, the seedlings thus appearing in small groups. The stone splits longitudinally into two pieces and the radicle emerges from the end of the stone through the opening thus made. The hypocotyl arches considerably, the cotyledons extricating themselves and leaving the testa behind.

THE SEEDLING (Fig. 76).

Roots: primary root moderately long, terete, tapering, wiry: lateral roots numerous, long, fibrous, developing early. *Hypocotyl* distinct from the root, 0·6–1·7 in. long, terete, tapering upwards, often with a bend at the base acquired during germination, white turning green, glabrous or very finely pubescent. *Cotyledons* sub-sessile, 0·3–0·5 in. by 0·1–0·15 in., plano-convex, somewhat fleshy, linear oblong, apex and base acute or slightly rounded, entire, green, glabrous. *Stem* erect, terete, green, minutely stellate pubescent; internodes 0·2–1 in. long. *Leaves* compound, exstipulate; first pair opposite, trifoliate, 1·1–1·5 in. long, common petiole 0·3–0·4 in. long, flattened above, minutely pubescent, leaflets variously lobed or divided; subsequent leaves alternate, once or twice pinnate, 3-, 5-, or 7-foliate or with trifoliate lateral pinnae. Rachis 0·8–3 in. long, flattened above, minutely pubescent. Terminal leaflet 0·8–1·5 in. long, ovate lanceolate, acuminate, base decurrent, irregularly lobed or divided, irregularly serrate; lateral leaflets opposite or sub-opposite, sub-sessile or with petioles up to 0·2 in. long, obliquely ovate lanceolate, acuminate, irregularly serrate, tripartite or otherwise lobed or in the form of trifoliate pinnae.

During the first season of growth the development of the seedling is moderate; by the end of the season it reaches a height of a few inches up to about 8–10 in.; the cotyledons usually persist until the end of the season. Under favourable conditions the development during the second and subsequent seasons is very rapid, a height of 5 to 8 ft. being attained by the end of the second season if regular weeding and watering are carried out; the tap-root by that time reaches a length of 2 to 3 ft. with considerable thickness and with long lateral roots. Under natural conditions, where no weeding and watering are done, the seedlings ordinarily reach a height of a few inches by the end of the first season of growth—that is, as a rule, the season after the fall of the seed—a height of a few inches to about 3 ft. by the end of the second season, and a maximum height of about 10 ft. by the end of the third season. These measurements were taken at Dehra Dun. Weeding greatly stimulates the development of the seedlings, and suppression retards it. Young plants appear to demand much light from an early stage: they suffer from frost in the winter, but not to the same extent as the neem. In northern India the growth of the seedlings ceases in November–December, and new growth starts about February–March. The leaves turn yellow and fall about December–January and the new leaves appear in March.

SILVICULTURAL CHARACTERS. The tree is a light-demander. It is more frost-hardy than the neem, though the seedlings suffer to some extent both from frost and from drought. Young plants are subject to browsing by deer. The tree coppices well and throws up root-suckers, especially where the roots are exposed or injured. The roots are chiefly superficial, and the tree is liable to be blown down in consequence; it is also very brittle, and branches are often snapped off, or the main stem is broken in two, by wind. Trees so broken down or cut high produce large numbers of shoots from dormant buds on the stem. Burrs are often produced on the stem, especially near the base. The tree is short-lived.

NATURAL REPRODUCTION. In the Changa Manga plantation the tree regenerates freely from seed.

ARTIFICIAL REPRODUCTION. Artificial propagation may be carried out by direct sowings or by transplanting seedlings from the nursery: the tree can also be grown from cuttings or from transplanted root-suckers. Experiments at Dehra Dun have shown that direct sowing is more successful than transplanting, which appears to check the growth to some extent. The fruits may be most conveniently collected in January–February when the trees are leafless. For raising plants in the nursery the fruits should be sown about 2–3 in. apart in drills from February to April or May and lightly covered with earth; the beds should be regularly watered and weeded, and the seedlings ordinarily commence to appear above ground about three weeks after sowing. Transplanting may be done in the first rains, when the seedlings are a few inches high, or towards the end of the cold weather, before new growth starts; in either case it is advisable to transplant with earth round the roots. Transplanting may also be done during the second rains, when the seedlings are often as much as 5 or 6 ft. high or more. In this case the stem should be cut off at about 4 in. from ground-level and the long taproot pruned down to about 9 in. in length: the plants stand this treatment well, and quickly start shooting up again. In frosty localities, at all events, this method is preferable to transplanting in the first season, since the plants can be protected in the nursery during the first winter. If kept until the second year in the seed-beds the seedlings will require thinning out in order to produce vigorous plants.

If direct sowings are carried out rapid development can be stimulated by thorough and regular weeding. Irrigation also promotes vigorous growth, having a more marked effect on this species than on the neem; irrigated and weeded line sowings, or, failing irrigation, weeded line sowings with or without the aid of field crops, or mound sowings, give most promise of success.

Plantations of this species require thinning from an early stage, as the saplings tend to become weakly if pressed for room.

RATE OF GROWTH. The rate of growth during the sapling stage, as already noted, is very rapid: this rapid growth is kept up for several years, during which a mean annual girth increment of 1·5 to 2 in. is not uncommon, but growth slows down before large dimensions are attained, and trees of large girth are often hollow. The concentric rings, which are annual, are distinct.

2. **Melia composita**, Willd. Syn. *M. robusta*, Roxb. Vern. *Labshi*, Nep.; *Maha limbu*, Uriya: *Karibevan*, Kan.: *Kuriaput*, Mar.

A large handsome deciduous tree of the eastern Himalaya, ascending to 6,000 ft., Assam, Khasi hills, Western Ghats and below *ghat* forests, moist low country of Ceylon, and possibly Burma. The wood is soft and reddish, and is used for planking, ceilings, and other purposes. It is a tree of moist localities and tropical forests, and is occasionally planted for ornament, though the fact that it is leafless for a short time detracts from its value as a roadside tree. The fruit, an ovoid drupe, ripens in the cold season. The growth is rapid. Gamble's specimens gave 2 to 3 rings per inch of radius (mean annual girth increment 2·09–3·14 in.) for a Madras specimen, and 7 rings per inch (mean annual girth increment 0·9 in.) for specimens from Bengal. Talbot says North Kanara specimens showed 3 to 4 rings per inch, giving a mean annual girth increment of 1·57–2·09 in.

3. CARAPA, Aublet.

Evergreen trees, the Indian species littoral.

Species 1. *C. moluccensis*, Lamk.: 2. *C. obovata*, Bl.

1. **Carapa moluccensis**, Lamk. Syn. *Xylocarpus Granatum*, Willd. Vern. *Pussur*, Sund.: *Ail*, Chittagong.

A moderate-sized evergreen tree with thin grey bark, attaining a height of 30–50 ft. Wood white, turning red on exposure, hard, used for house-posts, wheel-spokes, tool-handles, planking, and other purposes. This is one of the principal timber trees of the Sundarbans.

DISTRIBUTION AND HABITAT. Coast forests of Bengal, Andamans, Burma, the Malay Peninsula and Islands. In the Sundarbans, an account of which is given under *Heritiera Fomes*, it is now less common than formerly, its timber having been much sought after in the past. It occurs in the north of this tract in areas remote from the sea-face, chiefly in low-lying swampy localities associated with *Amoora cucullata*, *Sonneratia apetala*, *Avicennia officinalis*, and *Barringtonia racemosa*. It is not a gregarious species. In his report on the forests of the North Andamans, 1906, Mr. F. H. Todd says it is found at those points along the coast where the mangrove forest is absent, and grows close down to high tide level, mixed with *Ximenia americana*, *Cynometra ramiflora*, *Mimusops littoralis*, *Hibiscus tiliaceus*, *Heritiera littoralis*, *Mangifera foetida*, and *Calophyllum Inophyllum*, and that it is also found growing on flat alluvial clay close to mangrove swamps along with the last three species. In its natural habitat the tree grows in regions with an absolute maximum shade temperature of 98° to 102° F., an absolute minimum of 45° to 64° F., and a normal rainfall varying from 65 to 200 in. or more.

FRUITING. The fruits, which are globose capsules 3–5 in. in diameter, ripen in the Sundarbans about July. The capsules contain two or three seeds, somewhat variable in size, 2–2·7 in. long by 1·3–2 in. wide by 0·7–1 in. thick, irregularly angular or rounded, brown, with a thick and fibrous testa: in general shape and appearance the seed resembles a large Brazil nut. The seed, which is perishable, germinates soon after falling; it is buoyant and is thus adapted for dissemination by water.

GERMINATION (Fig. 77, *a–c*). Hypogeous. A somewhat thick mass of soft tissue, corresponding to the hypocotyl, first protrudes from the side of the seed, and from it issue the shoot and the roots, the latter in a cluster.

THE SEEDLING (Fig. 77).

Roots : A number of somewhat thick roots, with numerous fibrous lateral roots, clustered round base of stem. *Hypocotyl* a thick mass from which issue the roots and stem. *Cotyledons* conferruminate in a pinkish fleshy rounded or angular mass conforming to the shape of the seed and remaining within its thick fibrous testa ; petioles 0·2 in. long, broad and flattened. *Stem* erect, moderately thick, terete or slightly compressed, green or reddish, glabrous, in its earlier stages resembling a leafless asparagus shoot. *Leaves* alternate, simple, exstipulate. Petiole 1·5–3 in. long. Lamina 2·5–3·5 in. by 0·6–1 in., oblong lanceolate, acute or acuminate, entire, coriaceous, glabrous. Earlier leaves abortive, scale-like, caducous.

The early development of the seedling is very rapid. Within a month of germination the stem may reach a height of 16 in. or more, and in two months it may be well over 2 ft. in height. The first normal leaves are produced at the top of a considerable length of bare stem, on which the leaves are represented by caducous scales ; the young shoot during the first two or three weeks thus resembles the leafless shoot of an asparagus. This early stem development is an adaptation for bringing the foliage leaves as rapidly as possible out of the reach of floods, the thick starchy cotyledons meanwhile supplying the plant with food. Similar early development occurs in *Heritiera Fomes,* and a further study of the various species of the littoral forests may possibly reveal other instances of the same kind.

SILVICULTURAL CHARACTERS. The silvicultural characters of the tree have not yet been studied in detail. Like several other littoral species it produces pneumatophores.

RATE OF GROWTH. Gamble's specimens showed an average of 6·6 rings per inch of radius, representing a mean annual girth increment of 0·95 in., which is moderately fast. In the Sundarbans a minimum felling limit of 2 ft. girth is fixed for sound trees.

2. **Carapa obovata,** Bl. Syn. *Xylocarpus obovatus,* A. Juss. Vern. *Pinlè ôn*, Burm. ; *Dhundol,* Sund. ; *Karambola*, Chittagong.

A smaller tree than the preceding, with a crooked stem and large globose capsules 7–10 in. in diameter. It occurs in littoral forests of the Indian Peninsula, Sundarbans, Chittagong, Burma, the Andamans, Ceylon, extending to the Malay Archipelago, Africa, and Australia. Mr. C. G. Rogers[1] says that in the Andamans it occurs as a rule up the creeks, not immediately adjacent to the sea, along with *Rhizophora mucronata*, *R. conjugata*, *Ceriops Candolleana*, and *Kandelia Rheedii,* but that in certain localities it forms pure forests along the coast where true mangrove forests would have been expected. It does not produce pneumatophores like *C. moluccensis* : the roots are superficial and often ribbon-shaped, with sharp edges.

4. SOYMIDA, Adr. Juss.

Soymida febrifuga, Adr. Juss. Syn. *Swietenia febrifuga*, Roxb. Indian redwood. **Vern.** *Rohan, rohini*, Hind. ; *Sohan*, Uriya ; *Palara*, Mar. : *Suami*. Kan. ; *Shem*. **Tam.** ; *Sumi*. Tel.

---

[1] Report on the Exploration of the Forests of the South Andaman and adjacent Islands, 1906.

A moderate-sized to large almost deciduous tree with a straight trunk, and a fairly thick dark greyish brown bark exfoliating in large plates; leaves paripinnate, 9–15 in. long, with three to six leaflets 2–4·5 in. long. Wood dark reddish brown, very hard and durable, used for construction, agricultural implements, furniture, and other purposes.

DISTRIBUTION AND HABITAT. Common in the dry forests of the Indian Peninsula, extending northwards to Merwara, the Mirzapur hills, and Chota Nagpur (Hazaribagh, Palamau, &c.). It is particularly common in the dry forests of the Central Provinces, associated with *Chloroxylon Swietenia*, *Terminalia tomentosa*, *Acacia Catechu*, *A. leucophloea*, *Anogeissus latifolia*, *Phyllanthus Emblica*, *Diospyros Melanoxylon*, *Zizyphus Jujuba*, *Z. Xylopyrus*, *Cleistanthus collinus*, *Buchanania latifolia*, *Butea frondosa*, and other species. Where the soil is very poor, consisting largely of calcareous nodules or an excess of quartz, *Soymida* forms a characteristic open type of forest of very poor growth, in which the chief associate species are *Chloroxylon Swietenia* and *Acacia Catechu*, sometimes with *Gardenia* spp., and in which undergrowth is scanty or absent and even grass is limited in quantity. The tree is frequently found on dry stony hills and on laterite. In its natural habitat the absolute maximum shade temperature varies from 105° to 118° F., the absolute minimum from 32° to 50° F., and the normal rainfall from 25 to 60 in.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The young leaves, conspicuous from their red petioles and veins, appear in April–May, before all the old leaves have fallen. The large panicles of small greenish white flowers appear with the new leaves. The capsules ripen and shed their seed in July–August; they are smooth, 1–2 in. long, black when ripe, five-celled and five-valved, with numerous seeds in each cell. The seeds (Fig. 78, *a*) are soft, flat, winged at both ends, 1·5–1·8 in. by 0·5–0·6 in. (including the wings), with a thin papery testa and a soft felty covering, buff-coloured or light brown, with delicate wings; about 250 to 350 weigh 1 oz. The seeds are distributed by wind, and their felty covering is not only a protection for the soft seed, but also acts like a sponge in retaining water after rain, a valuable provision during germination in the dry localities which the tree so often frequents. The seed quickly loses its vitality.

GERMINATION (Fig. 78, *b–e*). Epigeous. The radicle emerges first, and the cotyledons then push their way up by the growth of petioles 0·4–0·5 in. long; the soft covering of the seed, part of which is often washed off by rain during germination, is either raised above ground and dropped with the expansion of the cotyledons or left on or just below ground. The young shoot then develops in the angle between the two petioles of the cotyledons.

THE SEEDLING (Fig. 78).

Roots: primary root long, at first thin, afterwards thickening greatly, terete, tapering, wiry, whitish at first, turning light brown: lateral roots few to moderate in number, fibrous, distributed down main root. *Hypocotyl* not very distinct from root, about 0·2 in. long, scarcely emerging from the soil. *Cotyledons*: petiole 0·4–1 in. long, channelled above, glabrous: lamina 0·6–0·8 in. by 0·6–0·8 in., orbicular or broadly ovate, apex rounded, base widely and prominently sagittate, entire, fleshy, green, glabrous, venation obscure, *Stem* erect, wiry, glabrous; internodes 0·1–0·2 in. long. *Leaves*, first pair

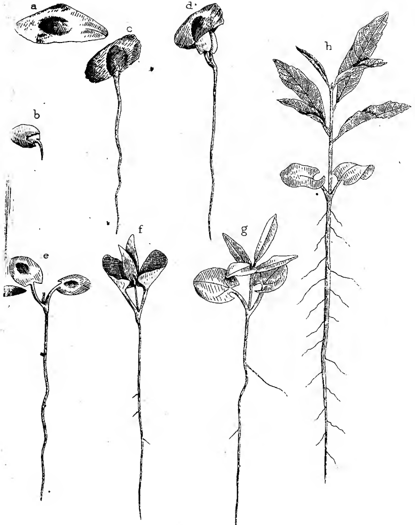

FIG. 78. *Soymida febrifuga*. Seedling × $\frac{7}{8}$.
a, seed ; *b–e*, germination stages ; *f–h*, development of seedling to end of first season.

opposite or sub-opposite, subsequent leaves alternate, approximate, simple in first season, exstipulate. Petiole 0·1–0·3 in. long, channelled above, often red. Lamina 1·2–4 in. by 0·4–0·6 in., up to 10 in. by 2·5 in. in second year, oblong lanceolate, apex and base acute, serrate, dark green, glabrous, venation prominently reticulate, lateral veins 12–20 pairs, principal veins often red. Compound leaves, first trifoliate then imparipinnate, commence to form in the second or third season.

The development of the seedling is very slow. Observations in Dehra Dun, which, however, is outside the natural habitat of the tree, show that during the first year the stem ordinarily attains a height of only 1–2 in., with a number of simple leaves crowded together: these leaves develop during the first month or two of growth in the rainy season. The cotyledons usually persist for 1½ to 2 months. By the end of the second year the height increases to 2–6 in., or as much as 12 in. if watering is done: by the end of the third and fourth seasons the heights attained are 8–15 in. and 1 ft. 6 in. to over 2 ft. respectively, the height being as much as 4 ft. if watering is done. By the third season a thick stem is developed in the more vigorous plants. Compound leaves begin to appear in the second season, the first ones usually being trifoliate. The earlier compound leaves of seedlings are usually imparipinnate, unlike those of the adult plant. The young leaves are sometimes brilliant red in colour, gradually turning to dark green. On damp badly-drained ground the seedlings are very liable to damp off, and even the seed does so and fails to germinate. The seedlings will not stand the competition of weeds, and respond at once to regular weeding: watering, provided this is moderate and the ground is not stiff, promotes somewhat more rapid growth. The seedlings are very sensitive to frost, which does most damage where weeds are prevalent: they are also subject to defoliation by insects. They show little or no growth after the end of the rains, and growth ceases altogether during the cold season, starting again about March.

SILVICULTURAL CHARACTERS. *Soymida febrifuga* stands the effects of drought and fire better than most of its associates; in the abnormal drought of 1899–1900 in the Indian Peninsula it escaped injury. It is somewhat frost-tender. It shows xerophytic adaptations in the felty covering of the seed already alluded to, the long thick taproot and the thickened stem of young saplings, the red young leaves of seedlings, and the red veins and petioles of the leaves. Mr. R. S. Pearson[1] classes it as a shade-bearer, and notes that in the Panch Mahals groups of seedlings and poles may be seen growing up happily through vertical shade. At Dehra Dun seedlings were found to require a good deal of light to promote the best development. The tree coppices moderately well and produces root-suckers.

NATURAL REPRODUCTION. Under natural conditions if timely rain falls germination ordinarily commences within a week. The conditions for successful natural reproduction have not yet been sufficiently studied, but as far as observations go factors of importance are a porous well-drained and not too moist soil, bare ground, or at all events the absence of dense weed-growth, freedom from all but the slightest frost, and sufficient light for the development of the seedlings. Some of the natural reproduction met with consists of root-

---

[1] Ind. Forester, xxxiv (1908), p. 208.

suckers, and in places these may be so plentiful that the tree appears in **gregarious** masses consisting of sucker shoots.

ARTIFICIAL REPRODUCTION. Experiments carried out in Dehra Dun have shown that direct sowing is more successful than transplanting nursery-raised plants ; the latter requires care and is fairly successful in the case of small plants a few weeks old. Direct sowings gave far more success, but it is essential that well-drained ground should be chosen and that the plants should be kept free from weeds. Sowings on ridges about 1 ft. high proved very successful.

RATE OF GROWTH. As far as is known the rate of growth is slow. The slow development of the seedling has already been referred to. Coppice-shoots are of slower growth than the majority of other species of the miscellaneous forests. Measurements of coppice-shoots one year old in Bhandara, Central Provinces, in 1912–13 showed an average height of 3 ft. 10 in. for *Soymida*, 3 ft. 11 in. for *Buchanania latifolia*, 6 ft. 4 in. for *Acacia Catechu*, 6 ft. 6 in. for *Terminalia tomentosa*, and 7 ft. 1 in. for teak.

Six trees planted in 1869 in a mango tope at Trichinopoly were measured by Mr. Rama Rao in 1916, when forty-seven years old, or say fifty years from seed. Their girths at breast-height varied from 5 ft. 2 in. to 7 ft. 5 in. and averaged 6 ft. 1·3 in., while the height of the boles to the first branch varied from 9 ft. 6 in. to 13 ft. and averaged 10 ft. 9 in. The trees stood near a tank, on deep red loam, and the growth in girth may be taken to be much faster than it would be under ordinary forest conditions.[1]

5. CHICKRASSIA, Adr. Juss.

The original spelling was *Chukrasia*.

Chickrassia tabularis, A. Juss. (Brandis regards *C. velutina*, Roemer, as a distinct species or very marked variety). Chittagong wood. Vern. *Chikrasi*, Beng. ; *Boga poma*, Ass. ; *Lal devdari, pabba*, Mar. ; *Dalmara*, Kan. ; *Sellangatchi, gantumali*, Mal. ; *Yinma*, Burm.

A very large handsome tree with a tall straight trunk, a spreading crown, and paripinnate leaves. Bark rusty brown, deeply fissured. Talbot says that in North Kanara it has a cylindrical trunk 60–80 ft. to the first branch and 14 ft. in girth. Rama Rao records a tree 18 ft. in girth in a temple grove on the Yelagiris in the Salem district, Madras. Wood reddish brown, hard, very ornamental, and suitable for furniture if well seasoned. The tree is worth cultivation.

DISTRIBUTION AND HABITAT. Sikkim, Assam, Chittagong, Burma, the Andamans, and the Indian Peninsula, chiefly in the Western Ghats ; also in Ceylon. The tree is usually found scattered in moist tropical forests on hilly country. Talbot says it is common in the rain-forests of North Kanara and the Konkan. Rama Rao says it is found on all hill ranges in the Salem district, Madras, above 2,500 ft., but that reckless fellings in the past have left but few specimens of large size, which are chiefly confined to temple groves religiously protected by the hill tribes. Bourdillon says it is thinly distributed through the evergreen forests of Travancore at elevations of 1,000 to 2,000 ft. In Burma it is scattered in tropical forests often in moist valleys. In Chittagong it is not uncommon in the hills. Kanjilal says it is fairly common in

---

[1] Ind. Forester, xliii (1917), p. 19.

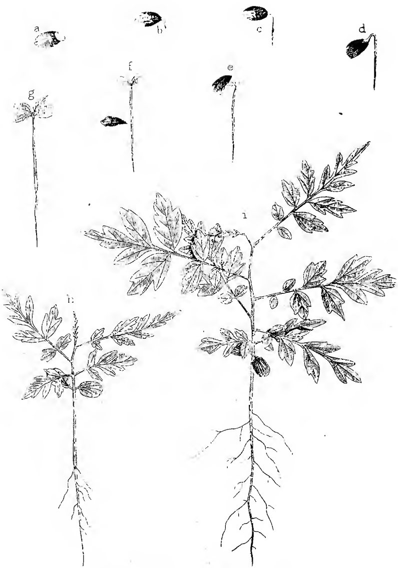

FIG. 79. *Chickrassia tabularis.* Seedling × $\frac{3}{4}$.
a, seed; *b–f*, germination stages; *g–i*, development of seedling to end of first season.

parts of Sibsagar, Assam, where owing to its superficial resemblance to *Cedrela Toona*, although it is considerably taller, it has escaped observation. In its natural habitat the absolute maximum shade temperature varies from 97° to 105° F., the absolute minimum from 37° to 60° F., and the normal rainfall from 70 to 150 in. or more.

LEAF-SHEDDING, FLOWERING, AND FRUITING. Kurz describes the tree as evergreen. Brandis says it is usually deciduous. Bourdillon says it is leafless in the cold weather. The yellowish white flowers appear in April–May and the woody ovoid dark brown capsules, about 1½ in. long, ripen from January to March. the winged seeds escaping and being disseminated by the wind. The empty capsules hang for some time on the tree after opening. The seeds (Fig. 79, *a*) are brown, flat, with a brown membranous wing twice the length of the remaining portion of the seed, the whole 0·5–0·7 in. by 0·3–0·4 in. Tests at Dehra Dun have shown that the seed will not retain its vitality for a year.

GERMINATION (Fig. 79, *b–f*). Epigeous. The radicle emerges from the end of the seed opposite the wing; the hypocotyl arches slightly at first and in straightening raises the cotyledons above ground, the testa either remaining on or under the ground or being carried up and dropped when the cotyledons expand.

THE SEEDLING (Fig. 79).

Roots: primary root moderately long, terete, tapering, wiry, pubescent: lateral roots moderately long and numerous, fibrous, distributed down main root. *Hypocotyl* distinct from root, 1–1·4 in. long, terete, tapering slightly upwards, tender at first, becoming wiry, white becoming green, pubescent, arched during germination. *Cotyledons*: petiole up to 0·12 in. long, flattened above, pubescent: lamina 0·4–0·5 in. by 0·25–0·3 in., foliaceous, elliptical, entire, apex and base rounded, glabrous above, minutely pubescent below. *Stem* erect, terete, woody, tomentose; internodes 0·2–0·7 in. long. *Leaves* compound, first pair opposite, subsequent leaves alternate, exstipulate. First pair 1–1·7 in. long, 5-foliate or 3-foliate with terminal leaflet deeply 3-partite. Subsequent leaves 5- or 7-foliate; rachis 1–3 in. long, pubescent; leaflets glabrescent above, puberulous below, very variable; terminal leaflet 1·2–2 in. long, ovate acuminate, deeply 3- or 5-lobed, base decurrent; lateral leaflets alternate or sub-opposite, irregularly ovate, acute or acuminate, variously lobed or divided, with short petioles up to 0·1 in. long.

Experiments at Dehra Dun showed that the growth of the seedling is moderately fast during the first year and very rapid during the second year. By the end of the first season a maximum height of 8 in. was attained, with a taproot about 6–8 in. long. By the end of the second season the plants had reached a height of 3 ft. 9 in. to 6 ft. 10 in., and were very vigorous: by the end of the third season they were 9 to 11 ft. in height, with a girth of 5 to 6 in. at 4 ft. from the ground. The experiments showed that a porous soil, protection from the sun, and only a limited amount of soil moisture are necessary for the germination of the seed and the development of the seedling. A stiff soil or an excess of soil moisture causes the seed to rot and the seedlings to damp off: on the other hand, the seedlings died off from drought if the soil was allowed to dry up. The seedlings suffered less from frost than might have been expected in a tropical species.

SILVICULTURAL CHARACTERS. The silvicultural characters of the tree have not yet been studied in detail. At Dehra Dun young trees were found to coppice well when felled; they were also found to be subject to the attacks of the toon twig-borer (*Hypsipyla robusta*).

ARTIFICIAL REPRODUCTION. Various trials have been made at Dehra Dun to ascertain the best method of raising the tree artificially. It is necessary to use fresh seed, which should be sown in March or April in light porous soil sheltered from the sun; watering should be done sparingly, but the soil should never be allowed to dry up as the seedlings are sensitive to drought. Germination ordinarily takes place in ten days to six weeks from date of sowing. The best results were obtained by raising seedlings in well-drained boxes or pots and pricking them out in nursery lines during August when they were a few inches high. Frequent weeding and loosening of the soil is necessary. Seedlings may be planted out either during the first rains or early in the second rains: the latter will probably be found preferable. Fair success has been attained by direct sowings on newly prepared ridges about 1 ft. high.

RATE OF GROWTH. Gamble's specimens gave an average of 8·6 rings per inch of radius, corresponding to a mean annual girth increment of about 0·74 in., which is moderate. Young trees grown at Dehra Dun reached in six years from sowing a height of 18 ft. and a girth of 1 ft. 6 in.

6. CEDRELA, Linn.

Trees with pinnate leaves and red wood resembling open-grained mahogany. Five (possibly more) Indian or Burmese species.

Species 1. *C. Toona*, Roxb.; 2. *C. serrata*, Royle; 3. *C. microcarpa*, C. DC.

1. **Cedrela Toona**, Roxb. Toon, red cedar, Moulmein cedar. Vern. *Tun, tuni, maha nim*, Hind.; *Todu*, Mar.; *Tundu*, Kan.; *Thevatharam*, Tam.; *Poma*, Ass.; *Thitkado, tawdama*, Burm. (Fig. 74.)

A large deciduous tree with a spreading crown and large paripinnate leaves 1–2 ft. long. Bark 0·4–0·5 in. thick, dark grey, red inside, smooth in young trees, afterwards longitudinally and transversely cracked and exfoliating in irregular woody scales. Wood red, soft, shining, somewhat resembling open-grained mahogany; much used for furniture, tea-boxes, cigar-boxes, and other purposes, and has been well reported on in the London market. The tree, owing to its rapid growth and the demand for its timber, deserves wider cultivation in localities suitable for it. The fact that its fresh new foliage appears before the commencement of the hot season makes it a very useful avenue tree in northern India. It sometimes attains very large size: Mr. A. K. Glasson measured a log in the Tista valley which contained 500 cub. ft. of timber.

DISTRIBUTION AND HABITAT. Sub-Himalayan tract and valleys of the outer Himalaya up to 4,000 ft., Chittagong, Assam, Burma, Chota Nagpur, Western Ghats and other hills of the Indian Peninsula. Frequently cultivated. In the western sub-Himalayan tract it is found chiefly in shady ravines and along streams, and often (as in the Dehra Dun valley) in swamp forests associated with *Trewia nudiflora*, *Ficus glomerata*, *Pterospermum acerifolium*, *Bischoffia javanica*, *Albizzia procera*, and other trees typical of moist situations. Farther east it is found in ravines of the outer hills and along the banks of streams, extending into Sikkim, Bhutan, and valleys farther east. Mr. W. R. Jacob says it is found in the lower forest of Bhutan up to 4,000 ft. and sometimes higher, associated with *Duabanga sonneratioides*, *Terminalia myriocarpa*, ***Michelia Champaca***, *Castanopsis indica*, and *Schima Wallichii*, and that occasionally patches of very fine toon trees occur. Mr. A. J. W. Milroy found it in the lower forests of the Abor country associated with *Castanopsis tribuloides*, ***Dysoxylum** Hamiltonii*, *Terminalia myriocarpa*, *Duabanga sonneratioides*, ***Amoora** Wallichii*, and others. It is met with in various localities throughout the Duars tract of Bengal and Assam, where it springs up readily on abandoned cultivation and on deep alluvial ground near rivers, associated with *Trewia nudiflora*. It occurs in certain valleys in Chota Nagpur. In the Central Provinces it is found in Balaghat and Bilaspur along valleys (Haines). Talbot says it is more or less abundant in the evergreen rain and monsoon forests of the Konkan and North Kanara, and is found in the dry forests of the Akrani, Khandesh. In southern India it occurs mainly in evergreen forests. In Burma it is found in tropical forests. Generally speaking, in its wild state it frequents moist localities, such as ravines, banks of streams, and even swamps, but if tended and watered in youth it is capable of growing in comparatively dry climates and situations, and has been extensively grown as a roadside tree in northern India. In its natural habitat the absolute maximum shade temperature varies from 95° to 110° F., the absolute minimum from 30° to 60° F., and the normal rainfall from 45 to 160 in. or more. Actually, however, it is cultivated in localities where the temperature reaches 120° and sinks below 30° F., and where the rainfall may be as low as 30 in.

Leaf-shedding, flowering, and fruiting. The time of shedding of the old leaves and appearance of the new ones varies greatly. In moist shady localities the leaves are retained longer than in drier situations; sometimes, in fact, the tree is said to be evergreen. In northern India the old leaves as a rule fall in December, but in certain cases the tree may remain in full leaf until February. The new leaves usually appear at the end of January and during February. When young they are dark red in colour; they develop rapidly, changing to bright green. The tree is extremely handsome when the new green foliage is out. Kurz says it sheds its leaves in the hot season in Burma. Bourdillon says that in Tranvancore it drops its leaves in September and is bare for some time.

In the Duars the flowers appear in February; in north-western India they do not usually appear till March or April. The small white flowers are arranged in lax panicles, and the petals quickly fall, whitening the ground around the trees. The five-valved capsules (Fig. 80, *a*, *b*), 0·7–1 in. long, in pendulous clusters, ripen in May and June (northern India), and the winged seeds escape at different times from the end of May till July, covering the ground for some distance around the trees: in the early rains they are washed into heaps. The clusters of empty capsules remain long on the tree: they may be seen hanging during the cold season when the trees are leafless, many persisting until February or March when the flowers are out. The seeds are light brown with a membranous wing at either end, 0·5–0·6 in. long including the wings: they are very light and are easily blown about by the wind: about 8,000 to 12,000 weigh 1 oz. Different samples of fresh seed were found to have a fertility varying from 60 to 80 per cent., but seed kept for one year failed to germinate. Records of seed-years maintained for several years in different parts of the United Provinces, Bengal, and Assam show that the tree usually seeds abundantly every year. The dates of flowering and fruiting given above refer to northern India; those given by various authorities in different localities are: (1) Burma, Fl. March–April, Fr. October–November (Kurz); (2) Bombay, Fl. January, Fr. March–April (Talbot); (3) Travancore, Fl. November to January, Fr. August to October (Bourdillon); (4) southern India, Fl. April–May (Beddome); (5) Central Provinces, Fl. March–April, Fr. May–June (Haines); (6) Chota Nagpur, Fl. March–April, Fr. June–July (Haines).

GERMINATION (Fig. 80, *c–g*). Epigeous. The radicle emerges from one end of the seed, the hypocotyl arches slightly, soon straightening and carrying the testa, with wings, above the ground: the testa quickly drops with the expansion of the cotyledons.

THE SEEDLING (Fig. 80).

Roots: primary root at first short and thin, afterwards long, much thickened and almost fleshy, terete, tapering, white turning yellowish brown: lateral roots numerous, long, fibrous. *Hypocotyl* distinct from root, 0·8–1·3 in. long, thin, terete, cylindrical, delicate, green, minutely tomentose, slightly arched during germination. *Cotyledons*: petiole 0·1 in. long, flattened above, minutely tomentose: lamina 0·3–0·4 in. by 0·2–0·25 in., foliaceous, elliptical or ovate, entire, apex rounded, base obtuse or acute, green, minutely pubescent at base, elsewhere glabrous. *Stem* erect, terete, delicate at first, afterwards wiry or woody, minutely tomentose: internodes 0·2–0·5 in. long. *Leaves* exstipulate, first pair simple or trifoliate, opposite or sub-opposite, subsequent leaves compound, alternate, earlier leaves trifoliate, later leaves to end of first season imparipinnate, 5- or 7-foliate. Simple leaves with petiole 0·15–0·3 in. long, channelled above, pubescent; lamina 0·3–0·7 in. long, pubescent or glabrescent, palminerved, variable, usually more or less tripartite, sometimes only slightly lobed, sometimes nearly trifoliate, lobes entire or coarsely and irregularly serrate or crenate. Compound leaves (first season) with rachis 0·3–0·8 in. long, leaflets variable, usually more or less 3-lobed, glabrous above, slightly pubescent beneath; terminal leaflet up to 1 by 0·6 in., lateral leaflets up to 0·6 by 0·3 in. Leaves of second season imparipinnate with three or more pairs of lateral leaflets; rachis 1·5–3·5 in. long, tomentose; leaflets 1–2·5 in. long, lanceolate or ovate lanceolate, acuminate, base acute, serrate or entire, glabrous above, pubescent beneath, venation pinnate.

During the first season the development of the seedling is moderate, a height of 4 to 9 in. being attained under favourable conditions. Although the seedlings make their way without difficulty through low and somewhat scanty weed-growth they are sensitive to suppression by dense heavy weeds, and succumb in large numbers where the weed-growth is dense; even if they survive they do not ordinarily attain a height of more than 2 or 3 in. by the end of the season. During the second season the growth is more rapid, a maximum height of over 5 ft. being attained, with a taproot up to $2\frac{1}{2}$ ft. long and 1 in. in diameter. During the second season the toon borer (*Hypsipyla robusta*, Moore) commences its ravages in the rains, boring down the pith of the leading shoots and killing them; this borer, the larva of a pyralid moth, is the cause of much interruption in the development of the young sapling, for although the whole plant is not killed the leading shoot dies down and growth has to be continued from new shoots below the original leader. By the end of the third season a maximum height of 7 ft. and an average height of about 4–6 ft. may be attained under favourable conditions: the growth, however, varies greatly in different individuals even under the same conditions, some remaining comparatively small for no apparent reason.

A plot of natural seedlings at Dehra Dun on ground covered with a low growth of grass and weeds in the open was kept under observation for three years; the heights attained by the end of the first, second, and third seasons respectively were 3–5 in., 18–24 in., and 3–4 ft. These measurements apply to north-western India. Under more favourable climatic conditions the rate of growth is faster: in the Buxa Duars natural saplings 10–14 ft. high have been found on a cultivated area abandoned three years previously.

Toon seedlings are not very sensitive to frost, but require shelter from a hot sun in the first season. Their development is poor on stiff soil, and they respond readily to loosening of the soil during weeding. In northern India they are leafless for a short time in the cold season: the season's growth continues till November or December and new growth begins in February or March.

SILVICULTURAL CHARACTERS. The toon is a moderate light-demander; it stands a moderate amount of shade in youth, the young plants requiring protection from the sun; afterwards it requires full overhead light and crown room for proper development. In its natural state it grows best in small gaps in the forest, where the ground remains moist, and the saplings obtain a certain amount of side protection with complete overhead light. In such places the tree develops a tall clean bole: when grown in the open it tends to branch lower down, forming a large crown. The tree is usually considered to be frost-hardy, both in the seedling stage and later: in the severe frost of 1905 in northern India it generally escaped damage. Parker,[1] however, notes that it does not do well in the Changa Manga plantation near Lahore, where it suffers much from frost when young. It is sensitive to fire, and does not stand much drought. One of the most serious dangers it is exposed to is the toon fruit- and shoot-borer (*Hypsipyla robusta*) referred to above. The life-history of this insect, and measures for dealing with the pest, have been fully described by Mr. C. F. C. Beeson.[2] Seedlings and saplings are often badly browsed by deer. For its best development the toon requires a deep rich moist loamy soil: it is sometimes grown in comparatively dry situations as a roadside tree, but here it requires watering in youth and is also liable to die off in case of excessive drought. The root-system is largely superficial, and the tree is thus harmful in the neighbourhood of field crops. The branches are often lopped for fodder, resulting in large decayed cavities in the tree.

NATURAL REPRODUCTION. Under natural conditions germination takes place soon after the fall of the seed, early in the rainy season or after the early showers preceding the monsoon. The large quantity of seed produced should ordinarily favour natural reproduction. Much of it, however, which falls before the monsoon breaks and is exposed to alternate wetting and drying with the early showers, is apt to fail: in spite of this a considerable proportion of the crop germinates from seed falling at the right time, and seedlings are often found in quantity round the base of walls and buildings or in other places to which the seed is washed by the rain. Large quantities of germinating seeds and young seedlings, however, are washed away or beaten down during

---

[1] For. Flora Punjab.

[2] Ind. For. Records, vol. vii, pt. vii, 1919.

Fig. 81. *Cedrela Toona*, natural reproduction, 10–14 ft. high, sprung up on cultivation abandoned 3 years previously, Buxa Duars, Bengal.

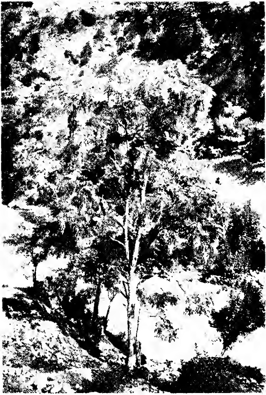

FIG. 82. *Cedrela serrata* in flower, Kagan Valley, Hazara

the heavy rains in the early part of the monsoon. In short grass and among weeds the seedlings also appear in quantity, but where weed-growth is heavy they tend to die off before long. Toon saplings are very often found establishing themselves by pushing their way up through bushes and hedges, to the base of which the seed is washed in quantity, protection from the sun being afforded during the establishment of the seedling. In the Duars toon reproduction is sometimes plentiful in rather open forest on deep soft alluvial sandy loam in the neighbourhood of rivers, where it establishes itself even in grazed areas. In the same tract it also regenerates well in the neighbourhood of seed-bearers in fire-protected savannah lands, particularly on abandoned cultivation, where it sometimes appears in quantity, holding its own with other species owing to its fast growth and its capacity for standing a fair amount of shade in youth (see Fig. 81). Experiments in Bengal have shown that by clearing the ground near seed-bearers a good crop of natural reproduction can be induced.

ARTIFICIAL REPRODUCTION. Numerous experiments in the artificial reproduction of the toon have been carried out at Dehra Dun. These show that direct sowings, whether broadcast, in lines with or without the aid of field crops, or on ridges, are not to be relied on owing to the loss occasioned by the washing away of the light seed, even when covered with earth, and the beating down or washing away of the young seedlings by the heavy monsoon rains. Thus, although surviving seedlings develop well if kept regularly weeded, the sowings invariably proved to be patchy and badly stocked. In Bengal, however, some success has been attained by direct sowings on lines cleared through the forest, and also in gaps 30 to 40 ft. square in which the ground was dug up and levelled and the seed was sown broadcast: the seedlings came up plentifully enough to allow of excess plants being transplanted into other parts of the forest. At Dehra Dun the best results have been attained by transplanting nursery-raised seedlings in the second rains, after pruning down the stems and roots.

The seed should be collected off the trees in May (northern India), and not off the ground, as much of the seed which reaches the ground and is exposed to alternate wetting and drying loses its vitality. It should be sown soon after collection in well-raised nursery beds, either broadcast or in drills, and lightly covered with fine earth. Regular watering is necessary, but great care is required to prevent the light seed from being washed away. A good plan is to cover the beds with a thin layer of grass and to water through a fine nozzle, the grass being removed as soon as the seedlings appear; otherwise watering by percolation is successful. In the first season the young seedlings should be protected by screens during the heat of the day unless the beds are shaded by trees. Regular weeding and loosening of the soil is essential. The seedlings require growing room, and if at all congested should be pricked out about 8 in. by 8 in. during the first rains. Transplanting is done early in the second rains, the stem being pruned down to about 3 in. from ground-level and the taproot being pruned down to about 9 in. Seedlings pruned down in this way have been found to transplant successfully and to develop vigorously. Transplanting may also be carried out during the cold season when the plants are leafless.

Rate of growth. The rate of growth is rapid. Gamble's specimens showed a growth varying from 3 to 9 rings per inch of radius, representing a mean annual girth increment of 0·7 to 2·1 in. Brandis's measurements of trees 30 and 35 years old on the Eastern Jumna Canal gave an average growth of 2½ to 3 rings per inch of radius, or a mean annual girth increment of 2·1 to 2·6 in. Gamble records the average measurements of 50 trees in the Kulsi plantation in Assam; these were found to have at an age of 22 years a height of 63 ft. and a girth of 22 in. Ring-countings on 12 stumps in the Tista valley, Bengal, gave a mean annual girth increment of 1·2 in. Two cross-sections in the silvicultural museum at Dehra Dun, from trees grown in that station, showed the following measurements:

1. Age 38 years; girth 4 ft. 5 in.: mean annual girth increment (over bark) 1·4 in.
2. Age 33 years; girth 4 ft. 4 in.; mean annual girth increment (over bark) 1·6 in.

Mr. F. Gleadow records the mean of four trees 16 years old in the Changa Manga irrigated plantation, Punjab, as 2 ft. 1½ in. in girth and 46 ft. in height. Measurements made in 1907 in plantations in the Thapal Grant estate, Saharanpur district, United Provinces, gave the following results:

1. Age 6 years; average girth 10·7 in.; average height 20·6 ft. (mean of 12 trees).
2. Age 16 years; average girth 2 ft. 7·5 in.; average height 33·9 ft. (mean of 77 trees).

2. **Cedrela serrata**, Royle. Hill toon. Vern. *Drawi*, *dalli*, *darlu*, *darli*, W. Him.

A moderate-sized to large deciduous tree of the western Himalaya up to 8,000 ft., Manipur, and Upper Burma. Leaves larger than those of *C. Toona*, 2–3 ft. long with 12–24 pairs of leaflets. Bark about 0·5 in. thick, with deep regular longitudinal fissures from an early age. The wood is light red, more open grained than that of the toon, and has an unpleasant odour when fresh: it is used for building, planking, and general carpentry. The tree is leafless during the cold season. The long drooping panicles of pink to nearly white flowers appear from May to July, and the capsules ripen in July–August; these are about 1 in. long, in pendulous clusters, and remain long on the tree after ripening. The seeds are winged only at the upper end. Fig. 82 shows a tree in flower. The tree produces root-suckers in great abundance; these sometimes form thickets to a considerable distance round the parent stem. Natural reproduction takes place readily on landslips, among loose boulders, or wherever new ground is exposed, particularly on the sides of ravines where there is a certain amount of moisture. The tree requires well-drained ground and situations which are not too dry. It is often cultivated in the hills for ornament, and Gamble says it has been introduced in Ceylon as a shade tree for tea, and that it is very largely planted for the same purpose over coffee in Java. The growth is rapid, Gamble's specimens showing as much as two rings per inch of radius, representing a mean annual girth increment of 3·14 in.

3. **Cedrela microcarpa**, C. DC. Toon (of the lower Darjeeling hills). Vern. as in *C. Toona*: *Tawdama*, Upper Burma.

A large evergreen tree with dark brown rough bark. Wood soft, red, used for planking and furniture.

Found throughout the outer ranges of the eastern Himalaya up to 6,000 ft., Assam, and Upper Burma. It grows best in depressions on deep rich soil, and does not thrive well on savannah lands. It should not be grown pure owing to its liability to the attacks of insects, particularly the twig-borer, and to the fact that it tends to produce a short bole unless drawn up by other fast-growing trees. In this respect the low-level birch and alder of the eastern Himalaya are good nurses for it, causing it to produce a long clean bole.

This tree is grown artificially in plantations in the lower Darjeeling hills. The flowers appear in December. The small winged seeds ripen in February and March, and should be collected off the trees and sown with as little delay as possible, as they soon lose their fertility. Plantations are invariably formed by planting out nursery-raised plants. The best results have been obtained in the Mongpoo plantations of the Cinchona department, the treatment being as follows: As soon as the seed is ripe it is sown in nursery beds well manured with leaf-mould, and is lightly covered. The beds are sheltered by means of a double roof of bamboo mats raised about 3 ft. above ground, the roof having a slight slope to allow rain to run off. The beds are kept watered and weeded, and when the seedlings are about three weeks old, they are pricked out about 3 in. apart. By the middle or end of June the seedlings are about 9 in. high, and they are then planted out with balls of earth, the planting holes, 18 in. deep, being dug at least two weeks previously. About a fortnight before the plants are removed from the nursery one of the bamboo mats forming the shelter over them is removed, and about four days later the second mat is removed in order to accustom the seedlings to grow in the open. For the first year after transplanting the young plants are carefully tended. Where the soil tends to become hard it is forked up, and in the case of drought the ground round the roots is covered with grass. In this way excellent results are obtained, plants only three years old sometimes attaining a height of 15 ft. These good results, however, are due in part to the fact that these plantations are formed on land previously under cultivation, where the soil has been well worked and freed from weeds and climbers. In the Forest Department the usual custom has been to sow the seeds in unmanured and unsheltered beds, the seedlings being pricked out about 6 in. apart when 3 in. high and planted out in the forest in their second and even in their third year, when they are usually about 1½ to 2 ft. high. The transplanting of small seedlings is avoided owing to the danger of their being suppressed by weeds and climbers.

7. CHLOROXYLON, DC.

Chloroxylon Swietenia, DC. Syn. *Swietenia Chloroxylon*, Roxb. Satinwood. Vern. *Bhera*, *girya*, Hind.; *Billa*, *billu*, Tel.; *Porasu*, Tam.; *Mashwal*, Kan.; *Halda*, *billu*, Mar.; *Hurgalu*, Mysore. (Fig. 83.)

A moderate-sized deciduous tree with a rather short bole and a spreading

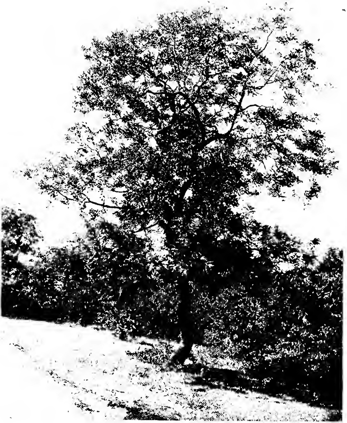

FIG. 83. *Chloroxylon Swietenia*, Belgaum district, Bombay.

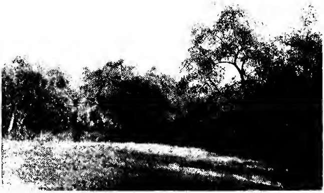

Fig. 84. *Zizyphus Jujuba* pure forest on alluvial sand and shingle, Siwaliks, United Provinces.

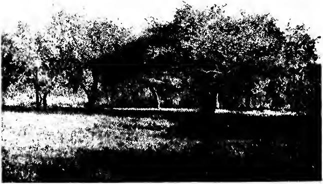

Fig. 85. *Zizyphus Xylopyrus*, Siwaliks, United Provinces.

light feathery crown with glaucous green, pinnate, aromatic leaves; bark thick, corky, yellow or light grey, aromatic. In India it does not often attain any great size, but in Ceylon it reaches a girth of 8 or 9 ft., though the bole rarely attains a length of over 30 ft.[1] This tree furnishes the well-known satinwood of commerce, used for all kinds of ornamental work.

Distribution and habitat. Common in the dry deciduous forests in the Indian Peninsula, extending as far north as the Satpuras and Chota Nagpur. Mr. Broun says that in Ceylon it is absent only in the south-western portion of the island, which is subject to the south-west monsoon, and from the higher mountain ranges; and although trees may be seen up to 1,500 ft. elevation, as a rule it may be said that it is not found above 800 ft. or in localities with a rainfall of over 65 in. In the Indian Peninsula it is common in dry types of mixed deciduous forest on metamorphic rocks, sandstone, and laterite, provided the soil is not stiff and clayey; it will grow on bare rocky ground and on poor soils if they are well drained and contain a large proportion of sand or gravel, and is found even on black cotton soil. It attains comparatively large size on sandy loam in the Chanda district. The satinwood is mixed with a variety of species which differ somewhat according to locality. Its chief associates are *Acacia Catechu*, *Terminalia tomentosa*, *T. Chebula*, *Anogeissus latifolia*, *Buchanania latifolia*, *Phyllanthus Emblica*, *Cleistanthus collinus*, *Cassia Fistula*, *Soymida febrifuga*, *Pterocarpus Marsupium*, *Dalbergia latifolia*, *D. paniculata*, *Albizzia Lebbek*, *A. odoratissima*, *Lagerstroemia parviflora*, *Diospyros Melanoxylon*, *Zizyphus Jujuba*, *Z. Xylopyrus*, *Cochlospermum Gossypium*, and other species typical of dry miscellaneous forest. Within a restricted area (North Arcot and neighbouring localities) *Pterocarpus santalinus* occurs with it, while in some districts *Hardwickia binata* is a common companion. In parts of Madras it occurs on very poor soil, often consisting of red sand, associated with *Albizzia amara*, *Acacia planifrons*, and *Dichrostachys cinerea*. It is sometimes typically found in association with *Soymida febrifuga* on poor calcareous soil with nodules of *kankar*.

In the Indian Peninsula it occurs in dry hot regions where the absolute maximum shade temperature may rise to nearly 120° F., the absolute minimum being 35° F., and the normal rainfall varies from 30 to 60 in.

Leaf-shedding, flowering, and fruiting. The tree is usually leafless from February to April or May. The panicles of small cream-coloured flowers appear in March–April, and the fruits ripen from May to August or sometimes later. The capsules are oblong, dark brown, coriaceous, 3-valved, 1–1·5 in. long. The seeds (Fig. 86, *a*) are brown with a broad wing at one end, the whole 0·6–0·8 in. long by 0·15–0·2 in. broad; the wing is brittle, with one margin broad and angular. The seed does not retain its vitality long. Records of seed-years show that as a general rule the tree seeds abundantly almost every year. The seed is adapted for dissemination by wind to moderate distances.

Germination (Fig. 86, *b–f*). Hypogeous. The radicle emerges at one end of the seed, and if the wing is still present at the time of germination the thin pointed plumule breaks through it. The cotyledons remain underground within the testa.

---

[1] A. F. Broun in *Ind. Forester*, xxv (1899), p. 181.

THE SEEDLING (Fig. 86).

Roots: primary root long, thick, terete, tapering, light brown: lateral roots moderate in number and length, thick. *Hypocotyl* somewhat indistinct, short, subterranean. *Cotyledons* sub-sessile or very shortly petiolate, 0·4 in. by 0·15 in., somewhat fleshy, obovate oblong, apex rounded, base broadly sagittate, outer surface slightly convex, inner concave, green, glabrous. *Stem* erect, terete, woody, green at first, turning light brown, young parts minutely pubescent or glabrous; internodes 0·1–0·3 in. long. *Leaves* compound paripinnate, first pair opposite, sub-opposite or alternate, subsequent leaves alternate; first few leaves with 3-5 pairs of leaflets, the number increasing in subsequent leaves up to 12 or more leaflets in seedlings one year old. Rachis 0·5–2·5 in. long, slender. Leaflets at first opposite or sub-opposite, afterwards alternate, shortly petiolate, 0·2–0·5 in. by 0·15–0·25 in., unequal sided, obliquely ovate or obovate, apex rounded, base obtuse or acute, obscurely crenate or entire, light green to pale glaucous green, paler beneath than above, glabrous, gland-dotted and aromatic.

The germinating seeds and young seedlings are very apt to be washed away by heavy rain, the exposed radicle drying up or being eaten by insects, and the seedling thus perishing. A long stout taproot is, however, quickly formed, and this saves many seedlings which would otherwise be washed away. Seedlings develop well on porous soil free from weeds and badly on stiff soil or where there is a thick growth of weeds, competition with which kills off large numbers of young plants. Experiments carried out at Dehra Dun showed that during the first season the development of the seedlings is very slow, a height of 2–3½ in. being ordinarily attained: at this time the young plants have several small compound leaves. During the second season the growth is faster, a maximum of 18 in. or more being attained by the end of the year under favourable conditions, though where seeds are prevalent the height may not exceed 3–6 in. During the third and fourth seasons the height increases to 2–3 ft. and 5–6 ft. respectively under favourable conditions, but where weeds are prevalent there may be little or no growth.

The leaves of seedlings turn yellow and fall in the cold season, the plants being leafless for a time. Their growth ceases from about October to March, when the new shoots appear. The seedlings are very frost-tender, particularly in the first year or two. In dry hot weather they are also liable to dry up partially or entirely, and benefit much from protection from the sun: they cannot, however, stand anything in the way of suppression, and if they are at all crowded the stronger individuals soon suppress and kill out the weaker ones.

SILVICULTURAL CHARACTERS. The satinwood is a strong light-demander, though the seedlings require protection from the sun in early youth. It is frost-tender, especially in the seedling stage, though severe frosts do not ordinarily occur within its natural habitat. It is easily damaged by fire, but its power of recovery from injury enables it to survive well in areas subjected to burning, hacking, and grazing. In parts of the Indian Peninsula it is much cut for fuel, while as soon as stems become large enough they are cut out for timber. The leaves contain an acrid oil which browsing animals, and even goats, find unpalatable, and this protects the plants from injury; for this reason the satinwood is often seen thriving on heavily grazed areas where most other species are browsed down. The satinwood is more keenly sought after than any of its associates by deer for the purpose of rubbing the velvet off their antlers, the bark of every tree being rubbed down where deer are plentiful; this is no doubt due mainly to the aromatic nature of the bark. The tree coppices and produces root-suckers, sometimes in great abundance. Recent experiments in North Chanda showed that in hardiness of coppicing —that is, percentage of stools surviving after coppicing—it was equal to *Pterocarpus Marsupium*, 58 per cent. of stools surviving as against 100 per cent. for *Lagerstroemia parviflora*, 98 per cent. for *Phyllanthus Emblica*, 95 per cent. for *Cleistanthus collinus*, 70 per cent. for *Anogeissus latifolia*, and 40 per cent. for *Diospyros Melanoxylon*. As regards insect and fungoid pests, Mr. Broun notes that the tree is liable to the attacks of insects which bore into the pith of the young shoots; also that a large number of trees die from the attacks of the larva of a beetle, probably a longicorn, which tunnels between the bark and the wood. He also mentions that in some parts of Ceylon the trees are liable to the attacks of a fungus which rots the centre of the tree and causes a clean hole sometimes throughout the length of the bole.

NATURAL REPRODUCTION. Under natural conditions, germination takes place during the rainy season, about 1–2 weeks after the fall of the seed, provided there is sufficient rain. The chief factors promoting successful reproduction by seed, where seed-bearers are present, are a well-drained light sandy soil, freedom from heavy weed-growth, protection against the sun in early youth, and thereafter an abundance of light. Numerous seedlings are often found coming up under a moderate cover of bushes such as *Zizyphus Jujuba*, *Carissa spinarum*, *Canthium parviflorum*, and others, while natural reproduction frequently springs up in clearings and along the sides of roads and lines through the forest, often under the shelter of bushes.

ARTIFICIAL REPRODUCTION. The satinwood has never been extensively cultivated artificially. In experiments carried out at Dehra Dun, good success was attained by direct sowings both on well-dug level ground and on raised ridges about 1 ft. high, provided that regular weeding was carried out from the time the seedlings appeared; unweeded sowings proved an entire failure, as did sowings on patches of stiff soil. Seedlings raised on well-prepared soil can be transplanted without much difficulty both in the first rains and in the second rains, provided earth is kept round the roots. As the seedlings are tender to frost and drought it is advisable to keep them under protection in the nursery for the first cold and hot seasons, and transplant them in the second rains. In the forest the necessary protection from the sun in early youth could be secured by sowing in cleared strips sheltered from the south by existing forest growth, or by raising the satinwood between lines of other species introduced a few years beforehand.

SILVICULTURAL TREATMENT. In India the miscellaneous forests containing satinwood are usually worked as coppice-with-standards, the satinwood being one of the trees retained as standards. It would probably not be difficult to obtain natural reproduction by opening the canopy slightly near seed-bearers by girdling or felling inferior species, care being taken not to open so heavily as to promote a strong growth of weeds. When the seedlings appear they would require to be kept free from weeds, while more light would have to be admitted by the further opening and, if necessary, the final removal of the canopy.

RATE OF GROWTH. The rate of growth is somewhat slow. Mr. Broun estimates the average rate in Ceylon to be 18 in. girth at 20 years, 3 ft. girth at 45 years, 4½ ft. girth at 75 years, and 6 ft. girth at 125 years, representing a mean annual girth increment varying from 0·9 in. in the earlier years to under 0·6 in. in later life. He reckons that the exploitable size may be taken to be 6 ft. girth, but in India it is doubtful if a girth of over 4 ft. would generally be obtained without the trees becoming overmature. In South Vellore, Madras, coppice growth is reported often to exceed 1½ in. in girth per annum.[1]

8. DYSOXYLUM, Blume.

A genus comprising several species of evergreen trees, for the most part shade-bearing and growing in moist or evergreen forests. The fruits are leathery capsules of fairly large size, containing large seeds with thick fleshy cotyledons, the seeds losing their vitality comparatively quickly and requiring moist shady ground on which to germinate.

Species, 1. *D. binectariferum*, Hook. f.; 2. *D. malabaricum*, Bedd.

1. **Dysoxylum binectariferum**, Hook. f. Syn. *D. macrocarpum*, Thw.

A moderate-sized to large evergreen tree of Sikkim, Assam, Chittagong, and the Western Ghats.

2. **Dysoxylum malabaricum**, Bedd. Syn. *D. glandulosum*, Talb. White cedar.

A very large evergreen tree of the evergreen forests of the Western Ghats from North Kanara southwards, Coorg, Anamalais, and Travancore. Flowering February to April; fruiting June–July. The wood is yellowish or light red, close grained, hard and elastic. The seed is large and heavy. Bourdillon says that in Travancore its reproduction is not altogether satisfactory, and this is corroborated by Mr. Tireman in Coorg; also that it has a tendency to be gregarious, and is frequently found in company with *Artocarpus hirsuta*, with an undergrowth of cardamoms. He says the growth is fairly fast in young trees, but is much slower later, and mentions a tree planted at Malayattur which attained a height of 27½ ft. and a girth of 12 in. in seven years; its girth was 15 in. in ten years. The wood is used in Cochin for oil-casks.

9. SANDORICUM, Cav.

Sandoricum indicum, Cav. Vern. *Thitto*, Burm.

A moderate-sized ornamental evergreen tree of the tropical forests of Burma, much cultivated for its fruit in Burma, and introduced into southern India and Ceylon. The crown is dense and shady and the leaves are trifoliate with sharp pointed leaflets. The fruit, which is yellow and velvety when ripe, is about the size of a small orange, and contains a mass of acid edible pulp. The seeds are brown and shiny with a felty arillus covering them. The fruit ripens towards the end of the hot season or in the rains. The cotyledons are oily, and the seeds soon lose their vitality. Seedlings can be most easily raised in baskets, in which they are planted out in the rains the year after sowing. The tree requires a moist climate and rich soil. The wood is red, moderately hard, and is used for building, carts, and boats.

---

[1] Madras Forest Report, 1915–16.

10. AMOORA, Roxb.

Species 1. *A. Rohituka*, W. and A.; 2. *A. cucullata*, Roxb.

1. **Amoora Rohituka,** W. and A. Vern. *Sohaga*, Oudh; *Bandriphal*, **Nep.**; *Pitraj*, Beng.; *Thitni*, Burm.

A moderate-sized handsome evergreen shade-bearing tree with a comparatively short bole and a dense spreading crown with large imparipinnate leaves. A widely distributed but seldom very abundant tree of the sub-Himalayan tract from Gonda and Gorakhpur eastwards through the *tarai*, the Bengal and Assam Duars and the outer hills up to 6,000 ft., Assam, Chittagong, Burma, Andamans, Chota Nagpur, western and southern India. Sometimes planted for ornament. The tree is typical of moist shady localities, occurring commonly in ravines, along the shady banks of streams, and in moist tropical forests. The fruit, a yellow leathery 3-valved capsule, 1·5–2 in. in diameter, ripens about January to May. The seeds, which are covered with a scarlet arillus, are oily and somewhat perishable. The seedlings and saplings come up under shade in moist situations, and natural reproduction is often plentiful under and around the parent trees.

2. **Amoora cucullata,** Roxb. Vern. *Amur*, *latmi*, Sund.: *Thitni*, Burm.

A moderate-sized evergreen tree of the coast forests of Bengal and Burma. In the Sundarbans forests (for a description of which see under *Heritiera Fomes*) the tree is now less common than it was formerly, having been much sought after in the past: it is found, together with *Carapa moluccensis*, mainly in low-lying swampy localities towards the north, at a distance from the sea. It is one of the species which send up pneumatophores. The wood, which is red and hard, is used for posts and other purposes.

11. SWIETENIA, Linn.

Two species of *Swietenia* have been more or less extensively cultivated in India in gardens, along roads, and in the forest; these are 1. *S. Mahagoni*, Linn., the true mahogany tree of Central America and Jamaica; and 2. *S. macrophylla*, King, the large-leaved mahogany, which has much larger leaves and capsules.

1. **Swietenia Mahagoni,** Linn. Mahogany.

Past experiments. The cultivation of the true mahogany was first attempted in India in 1795, when plants from the West Indies were introduced into the Royal Botanic Gardens, Calcutta. It was propagated subsequently by layers, until from 1865 arrangements were made for consignments of seed from the West Indies, and the tree has since then been grown with varying success in many parts of India.

In Bengal, mahogany has succeeded admirably in the Royal Botanic Gardens, Calcutta, there being at present over 200 trees in the Gardens, the oldest dating from 1795: many of the larger trees were blown down in a cyclone in 1864, and their timber fetched the current market price for good mahogany. The survivors are well grown with straight clean boles. At Barrackpore there are also some fine trees: those on the Calcutta maidan are not so good. In the Raj Gardens at Durbhanga there are about a thousand trees, planted 10 ft. apart about 1882–7. A plantation was formed in the Mohurgong forest in the Darjeeling *tarai* with plants obtained from seed imported in 1865, but it proved a failure. It has also failed at Bamunpokri in the lower Darjeeling hills: here the plants grew well at first, but almost invariably died when about 4–6 ft. high. There are a few trees in the Palamau forest division of Bihar and Orissa, which have done moderately well. In the United Provinces there are trees in good condition in the Government Gardens at Cawnpore, Allahabad, Lucknow, and Saharanpur: at Dehra Dun it has not proved a success. In the Punjab seeds were sown in the Changa Manga and Phillour plantations in 1886, but the experiment was a failure. In the Central Provinces mahogany trees have done fairly well in North Chanda, but their development has not been altogether satisfactory. In Assam experiments made in 1878–9 also resulted in failure: a few plants survived until 1884–5, but all have since died. In Burma various experiments have been made since 1878 in the Tharrawaddy and Rangoon forest divisions, but only a few trees now survive, the majority showing poor development: in some cases this may be attributed to the stiffness of the soil in which they were grown. From 1838 to 1842 mahogany seedlings were planted out with success in Akyab on flat sandy alluvium: the diameter-growth was very rapid (see measurements recorded below), but since the trees were grown in more or less isolated positions, height-growth was sacrificed to crown development. In the Andamans experiments were made in 1898–9 to grow mahogany, but the great majority of plants either died out or showed poor development, mainly owing to insect attacks. In 1906 the survivors, then seven years old, were 15 to 20 ft. in height. In Madras it has been tried in many localities, but in the majority of cases the results have not been satisfactory, owing partly to conditions of soil and climate and partly to insect attacks. Experimental sowings have proved more or less unsatisfactory in Godavari, Kistna, Bellary, Salem, Cuddapah, Nellore, North Arcot, and other districts; in the alluvial soils of the Trichinopoly Paduzais more successful results have been obtained. In the Agri-Horticultural Society's Garden at Madras and in other parts of the town there are trees of various ages up to eighty years or more; most of these have succeeded well. In Madura some trees have succeeded well, and the older ones commenced some years ago to regenerate naturally from seed. In South Canara also there are some fairly well grown trees. In South Malabar experiments began in 1872 and have been continued subsequently, but on the whole the results have not been good, owing partly to unsuitable soil conditions and partly to damage by deer and by insects: *S. macrophylla* has here succeeded better than *S. Mahagoni*. In Bombay there are a few trees, the oldest dating from about 1870, doing well in the Bombay Victoria Gardens and in the Poona Garden there are also several well-grown trees, probably dating from about the same time. In Baroda varying success has been met with: generally it has been found necessary to water during the first five years.

SILVICULTURAL CHARACTERS AND TREATMENT. The planting of mahogany on a commercial scale in India has been suggested on more than one occasion, and the results of the experiments undertaken hitherto are of value in this connexion. The success attending the cultivation of the mahogany tree has been much greater in gardens than in forest plantations: this would indicate that the degree of tending and of protection from insects and other sources of injury must influence the results to a great extent, while no doubt, like other *Meliaceae*, it requires careful weeding in the earlier stages. The tree thrives best in a moist warm climate on deep rich soil which should not be stiff; Bourdillon, writing of the tree in Travancore, says it requires an exceptionally free and well drained, even sandy soil, otherwise it is apt to suffer from canker of the shoots. It has also succeeded best so far in localities not far removed from the sea and at elevations not much above sea-level. In dry climates and on poor soils it is a complete failure. At Durbhanga trees have occasionally been subjected to prolonged inundation without any apparent bad effects. The tree fruits well in India and produces fertile seed sometimes at as early an age as 20 years, though as a rule it does not seed until it is about 30–40 years old. It does not stand much shade; experiments at Nilambur in planting it under teak proved a failure. In some localities insects greatly damage the trees, preventing their development and even killing the smaller individuals; among others the toon twig-borer (*Hypsipyla robusta*) does much damage to the young shoots. Seedlings and saplings are subject to injury by deer and pigs, while monkeys damage the trees by breaking the branches for the sake of the succulent twigs and the bark. For artificial propagation the plants are usually raised in baskets or deep narrow pots and planted out when about 1 ft. high, the pots being broken in the planting pits. In India the flowers appear in April–May, and the fruits ripen from October to December. Mr. Rama Rao[1] records a case of normal flowers being produced by a seedling barely ten months old in April 1913 at Quilon in Travancore. Another case of precocious flowering is described by Hemsley in Hooker's *Icones Plantarum*. Plate 2786, under the name of *S. Mahagoni* var. *praecociflora*, from material sent from the Royal Botanic Gardens, Trinidad: the seedlings in question were 6–10 in. high, but in this case the flowers were abnormal in certain respects.

RATE OF GROWTH. In India the rate of growth of the mahogany tree is very rapid in localities where it has been grown with success. Gamble instances measurements recorded by Dr. T. Anderson in 1866 showing that three trees at Calcutta, presumably 73 years of age, had girths of 14 ft. 3 in., 12 ft. 3 in., and 13 ft. respectively, representing a mean annual girth increment of nearly 2·2 in. Trees introduced in 1795 into the Royal Botanic Gardens, Calcutta, had attained in 1864 a girth of 12 ft. (mean annual girth increment 2·1 in.), and in 1907 a girth of 14 to 18 ft. (mean annual girth increment 1·5–1·9 in.) with a height of 120 to 130 ft. Ten trees with a mean age of 58 years, measured at Saharanpur in 1872, had a mean annual girth increment of 1·26 in., representing an average girth of slightly over 6 ft. Mr. J. Nisbet[2] records measurements made by him at Akyab in 1881 of ten trees then about 42 years old: the total height varied from 36 to 60 ft., the length of bole from 5 to 9 ft., and the girth at 5 ft. from ground-level from 5 ft. 5 in. to 10 ft. 1 in. The average girth was 6 ft. 10 in., representing a mean annual girth increment of 1·95 in. These trees grew for the most part in open situations, and height-growth was sacrificed to crown and girth development. Gamble mentions a section cut at Nilambur showing 2·2 rings per inch of radius, representing a mean annual girth increment of 2·9 in. In the Andamans, young trees eight years old were 15 to 20 ft. high. In the Bombay Victoria Gardens, trees ten years old had a height of 25 ft., and trees thirty to forty years old a height of 50 to 60 ft. Four trees thirty-five years old, measured at Muzaffarpur in 1913, varied in girth from 7 ft. to 7 ft. 8 in. and averaged 7 ft. 4 in., representing a mean annual girth increment of 2·5 in.; these trees were grown in open situations, and had short boles 6 to 12 ft. in length. Nearly all the measurements quoted above are those of trees grown under more than ordinarily favourable conditions so far as girth development is concerned: in forest plantations a considerably lower rate of growth would have to be allowed for.

---

[1] Ind. Forester, xxxix (1913), p. 327.

[2] *Ibid.*, vii (1881-2), p. 250.

2. **Swietenia macrophylla**, King. Large-leaved mahogany.

CULTIVATION IN INDIA. This tree grows even more rapidly and thrives better in India than *S. Mahagoni*, from which it is easily distinguished by its much larger leaves and capsules, the latter being 6 in. long. Seeds believed to have been obtained from Honduras, and labelled 'mahogany', were first introduced into India through the India Office, in 1872. The seedlings were soon noticed to be different from those of the true mahogany, and when the trees flowered and fruited in their twelfth and thirteenth years, the material available was examined by Dr. King, who described the tree as a new species. It is a very ornamental tree and thrives well in many parts of India, growing rapidly and seeding freely at an earlier age than the true mahogany. It grows well as far north as Dehra Dun, where it produces seed at a comparatively early age. The wood is somewhat similar to that of the true mahogany, but is paler in colour, and may possibly not prove to be of such good quality. Mr. A. Wimbush says he was not impressed with a plank cut from a tree eighteen years old removed in thinning the Eddacode plantation, South Malabar, in 1911: it was almost white, with a slight pinkish tinge, and was bored into by some very minute borer. Possibly in the case of older trees the wood may prove to be of better quality. The tree is less exacting as regards both soil and climate than the true mahogany. In South Malabar it has been found to grow well on disintegrated laterite soil, but not on bare laterite: in this district it may be said to have passed the experimental stage, and is now grown in plantations, while the older trees are regenerating naturally from seed. It does not stand much shade, and cannot be grown under teak. It is subject to damage by insects; young saplings are readily browsed by deer and goats, and are uprooted by pigs, while the twigs are, as in the case of the true mahogany, broken by monkeys: the trees are also much barked by deer. Basket planting is the usual method of propagating the tree. In South India it flowers from February to May, and the fruits ripen in December–January.

RATE OF GROWTH. Under favourable conditions the rate of growth is rapid. In the Royal Botanic Gardens, Calcutta, trees planted in 1872 reached a maximum height of 20 ft. in 12 years. In the Peradeniya Gardens, Ceylon, a height of 40 ft. has been reached in 11 years. A tree planted in 1873 at Chathamborai, South Malabar, at an age of 35 years had a height of 95 ft. and a girth of 7 ft. 5 in., and at an age of 39 years had a height of 100 ft. and a girth of 8 ft. 5 in., representing a mean annual girth increment of over 2·5 in. In 1911–12 the trees in the Pokote and Eddacode plantations of South Malabar showed a mean annual girth increment of 2 in., at which rate girths of 6 ft. and 7 ft. might be expected in 31 and 42 years respectively.

ORDER XVII. ILICINEAE

This order, comprising the one genus *Ilex* (holly) with between twenty and thirty species, is of small importance from a forest point of view. The trees are for the most part evergreen hill species with shade-bearing tendencies: several have spinous-toothed leaves.

ILEX, Linn.

Species 1. *I. insignis*, Hook. f.; 2. *I. dipyrena*, Wall.; 3. *I. denticulata*, Wall.; 4. *I. Wightiana*, Wall.

1. **Ilex insignis,** Hook. f. Vern. *Lasuni*, Nep.

A small evergreen tree with large prickly leaves and bright red berries which ripen in the winter: the common holly of Darjeeling.

2. **Ilex dipyrena,** Wall. Himalayan holly. Vern. *Kanderu*, Jaunsar; *Shangala*, Punjab.

A moderate-sized evergreen tree of the western Himalaya from Bhutan westwards at 5,000 ft. upwards. In favourable situations it ordinarily attains a height of 40–50 ft. and a girth of 4½ ft., though trees of much larger girth have been recorded. Bark light yellowish grey, smooth, often moss-covered, becoming dark greenish brown and rougher in old trees. The leaves are stiffly coriaceous, spinous serrate or entire. The clusters of greenish white flowers appear from April to June, and the dense clusters of red berries commence ripening in October and continue to ripen in the winter, the quantity produced varying in different years. The tree is a strong shade-bearer, and prefers cool damp shady places, particularly along moist ravines.

3. **Ilex denticulata,** Wall.

A large tree of the Nilgiris and Anamalais, common in sholas at 6,000–8,000 ft.

4. **Ilex Wightiana,** Wall.

A large tree of the hills of southern India; common in the Nilgiri sholas, and conspicuous from its white flowers and red berries. In Travancore at 4,000 ft. in evergreen forest on the Peermerd plateau (Bourdillon).

ORDER XVIII. CELASTRACEAE

This order is of comparatively small importance in Indian forestry, comprising for the most part small trees, shrubs, and climbers. There are several Himalayan species of *Euonymus*, small evergreen or deciduous trees or shrubs, with even-grained compact white or yellowish wood used for carving; some of these (e.g. *E. tingens*, Wall.) are characterized by a capacity for producing root-suckers in great abundance, especially where the roots are exposed, and are thus useful for consolidating and retaining hill slopes and cuttings.

Genera 1. LOPHOPETALUM, Wight; 2. ELAEODENDRON, Jacq. f.

1. LOPHOPETALUM, Wight.

Lophopetalum Wightianum, Arn. Vern. *Balpale*, Kan.; *Venkotta*, Mal.

A very large evergreen tree of the west of the Indian Peninsula from the Konkan southwards, up to 3,000 ft. in the Western Ghats, in evergreen forests.

In Travancore it is common in the evergreen forests and on river banks at low elevations, sometimes ascending to 2,000 ft. (Bourdillon). **Fl.** January to April. **Fr.** June–July. Gamble says the wood is much esteemed in South Canara, where it is used for house-building. Bourdillon says it grows fast and could easily be propagated.

2. ELAEODENDRON, Jacq. f.

Elaeodendron glaucum, Pers. Syn. *E. Roxburghii*, W. and A. Vern. *Bakra, dhebri, jamrasi, chauri*, Hind.; *Tamruj*, Mar.; *Mukarki*, Kan.; *Karuvali*, Tam.

A deciduous (nearly evergreen) tree, small to moderate sized in drier localities, attaining large dimensions in moist or evergreen forests. Branchlets often reddish, leaves opposite or sub-opposite, dark green and shining above, glaucous beneath. Bark fairly thin, dark grey or reddish, smooth or exfoliating in small quadrangular scales, red inside and exuding a copious watery sap when cut. The wood is used for cabinet-work and picture frames.

Distribution and habitat. Though not abundant anywhere the tree is fairly widely scattered throughout many parts of India, in the sub-Himalayan tract and outer Himalaya, Oudh, Chota Nagpur, the Central Provinces, and the Indian Peninsula generally. It is most commonly found in mixed deciduous forests, or scattered in sal forest in the sub-Himalayan tract: on the boulder terraces of the outer Himalaya it is sometimes fairly plentiful, as at Kalsi in the Dehra Dun district. It is often found on clay soil. In the Central Provinces it is common on trap and on metamorphic rock (Haines). In the Western Ghats it attains large dimensions in moist evergreen forest.

Leaf-shedding, flowering, and fruiting. The tree is leafless or nearly so in March–April, the new leaves appearing in May (northern India). The dates of flowering and fruiting appear to vary considerably. There are possibly two flowering periods, February to June and September to December. The fruit is a rather dry obovoid drupe 0·4–0·7 in. long; the outer portion dries into a brittle shell, which is filled by the oily seed with a reddish brown papery testa. In some localities the fruits begin to ripen in November, in others not till January, while they continue ripening for some time afterwards. Before ripening they are much subject to attacks of parrots, which break them open to get at the kernel inside. At the time of ripening they are eagerly sought after by hornbills, which probably help to spread the seed. Tests carried out at Dehra Dun showed a fertility of 60 per cent. in fresh seed and 20 per cent. in seed kept for one year.

Germination and development of seedling. Germination, which is epigeous, takes place under natural conditions at the commencement of the rains: the cotyledons persist for about two to three months. The first pair of foliage leaves are opposite, the subsequent leaves of the seedling being alternate. By the end of the first season the seedlings reach a maximum height of about 7 in. with a dark yellow taproot several inches long; they lose their leaves about January–February or sometimes not till the new shoots appear in March. During the second and third seasons the growth is slow, averaging only about 2–4 in. per annum. Weeding, if carried out from the time the seed is sown, stimulates development, but the sudden removal of weeds over seedlings previously unweeded is liable to result in the death of the seedlings, which are tender to drought. Numbers of germinating seedlings perish through drying up when the seed germinates on the surface of the ground without becoming covered with earth. The seedlings appear able to struggle successfully against weed-growth, though their development is impeded by it. The seedlings are moderately frost-hardy. They are liable to damage by insects, which sometimes kill them.

SILVICULTURAL CHARACTERS. The tree is a moderate shade-bearer. It is fairly frost-hardy. It produces root-suckers, and frequently regenerates by this means. It is sometimes supposed that regeneration is obtained entirely by root-suckers, the seed being sterile, but, as already noted, tests and experiments at Dehra Dun have shown that this is not the case.

ARTIFICIAL REPRODUCTION. If seed be sown in drills in the nursery in March or April, lightly covered with earth and watered, the seedlings appear above ground in about four or five weeks, and may be planted out during the first rains when a few inches high. They stand transplanting only moderately well, some dying back but as a rule recovering.

RATE OF GROWTH. The rate of growth is slow. Periodical measurements of trees 1½–3 ft. in girth in three sal sample plots in the Lansdowne division, United Provinces, showed mean annual girth increments of 0·35, 0·11, and 0·20 in. as compared with 0·54, 0·26, and 0·25 in. respectively in the case of sal of the same dimensions.

ORDER XIX. RHAMNACEAE

With the exception of certain members of the genus *Zizyphus*, this order is not an important one silviculturally; it consists mainly of shrubs, some of them climbing or straggling, and small trees of little importance.

ZIZYPHUS, Juss.

Trees or shrubs, some climbing or straggling, usually armed with stipular prickles. The fruit is a drupe, as a rule fleshy; the fruits of many species are devoured by birds and animals, and the seeds are spread by their agency.

Species 1. *Z. Jujuba*, Lam.; 2. *Z. Xylopyrus*, Willd.; 3. *Z. vulgaris*, Lam.; 4. *Z. nummularia*, W. and A.; 5. *Z. Oenoplia*, Mill.; 6. *Z. rugosa*, Lam.

1. **Zizyphus Jujuba, Lam.** Vern. *Ber*, Hind.: *Jelachi*, Kan.; *Bor*, Mar.; *Yellandai*, Tam.; *Regu*, Tel.; *Zi*, Burm. The cultivated form is known as *pewandi ber*, *seo ber*, or *kabuli ber*.

A small to moderate-sized deciduous (almost evergreen) tree with a short bole, spreading rounded crown, and drooping branches armed with stipular prickles. Bark dark grey or nearly black, with long vertical fissures, reddish and fibrous inside. The tree is very variable in size and general appearance, and in the size and shape of its fruits; a low shrubby form is common on grass-lands in many localities. The tree sometimes reaches large dimensions. Mr. E. D. M. Hooper[1] records a tree 80 ft. high, 16 ft. 9 in. in girth at 5 ft.

---

[1] Ind. Forester, vii (1881–2), p. 259.

from ground-level and 23 ft. at the base, which he found growing on a small knoll on laterite soil on the site of an old village near the Weinganga river, Central Provinces.

The tree is a useful one in furnishing fuel and small timber in dry regions, as well as thorns for fencing in agricultural districts; the branches are lopped for cattle fodder, and the leaves are one of the foods of the tasar silkworm. It is cultivated throughout India for its fruit, and the wild fruits are also edible. In some localities the lac insect thrives on the tree. The wood is used for saddle-trees, agricultural implements, and many other purposes, and gives good fuel and charcoal. Silviculturally the tree, in its bushy form, may be of great value in enabling other trees, for example *Bombax malabaricum*, to establish themselves in heavily grazed areas (see under *Bombax malabaricum*, p. 139, and Fig. 61).

DISTRIBUTION AND HABITAT. *Zizyphus Jujuba* is found throughout the greater part of India, either wild or naturalized, ascending to 5,000 ft. in the Himalaya (e.g. on waste land in valleys in the Kumaun hills); it thrives in comparatively dry regions, where it is often gregarious either in the tree form or in the bushy form in grass-lands, its most frequent companion being *Acacia Catechu*. It thrives best on sandy or shingly alluvium and on arable land, but grows on a variety of soils, including laterite, black cotton soil, and even moderately saline soil, while it appears on open waste lands on poor dry ground; it springs up readily on abandoned cultivation in dry localities. On the sandy or gravelly alluvium of dry river-beds it often forms pure crops which in time give place to other species (Fig. 84).

The tree grows wild or naturalized in localities where the absolute maximum shade temperature varies from 100° to over 120° F., the absolute minimum from under 20° to about 55° F., and the normal rainfall from 5 to 90 in. or more.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The old leaves fall about March–April and the new leaves appear at the same time.

The small greenish yellow flowers appear from April to October, the period varying in different localities. The fruits ripen from October to March. In the wild form the drupes are more or less globose, 0·5–0·8 in. long, orange or red when ripe, with a mealy sub-acid pleasantly flavoured pulp in which is the hard furrowed two-celled and two-seeded stone (Fig. 87, *a*, *b*). The seed has a brown papery testa. The cultivated fruits are larger (about 1·5 in. long) and more ellipsoidal.

In the wild state the tree usually fruits well every year, producing an abundant crop. Tests carried out at Dehra Dun have shown that the seed retains its vitality for at least 2½ years, though the percentage of fertility of old seed is less than that of fresh seed.

GERMINATION (Fig. 87, *c–f*). Epigeous, and similar to that of the teak. The hard stone splits down two sutures which divide it into three parts, namely, the two valves consisting of the outer walls of the cells, and the central wall between the two cells. The cotyledons emerge through the sutures, leaving the seed-coats within the cells, and the radicles push their way downwards; the walls of the stone remain on or in the ground. As a rule two seedlings appear from each stone, one or both of which may become established.

THE SEEDLING (Fig. 87).

Roots : primary root long, terete, tapering, wiry : lateral roots moderate in number, fibrous, distributed down main root. *Hypocotyl* distinct from the root, 0·3–0·8 in. long, terete or slightly compressed, cylindrical or tapering up or down, green. *Cotyledons* : petiole 0·4–0·6 in. long, flattened above, glabrous: lamina 0·4–0·6 in. by 0·4–0·6 in., foliaceous, orbicular, apex truncate, base tapering slightly, entire, green, glabrous, 5-veined from base, three veins more prominent than the others. *Stem* erect, terete, wiry, green, tomentose ; internodes 0·4–1·2 in. long. *Leaves* simple, first pair opposite and smaller than the others, subsequent leaves alternate. Stipules up to 0·15 in. long, spinescent. Petiole 0·1–0·2 in. long, channelled above, tomentose. Lamina, first pair 0·7–1·2 in. by 0·6 in., subsequent leaves 1·2–2·5 in. by 0·6–1·2 in., ovate or elliptical, apex acute or rounded, mucronate, base acute or rounded, serrate or nearly entire, glabrous above, sparsely pubescent beneath, prominently 3-veined from the base.

The development of the seedling varies greatly according to the treatment it receives. On loose soil, if weeding and watering is carried out and if the plants grow in full sunlight, the growth is rapid, a maximum length of stem of as much as 2–2½ ft. and 3–4 ft. being attained by the end of the first and second seasons respectively ; the growth is always straggly, and by the end of the third season a thick bushy growth of plants up to 5 ft. high may be obtained under similar favourable conditions. Under ordinary natural conditions the development is much slower, a height of 2 to 5 in. being usually attained by the end of the first season, increasing to about 7 to 14 in. by the end of the second season. The seedling has a long wiry taproot : nursery plants dug up in the second season have been found to have taproots as much as 4 ft. in length. Vigorous nursery-raised plants of the wild variety have been found to flower for the first time in the second season, and to produce an abundant crop of fruit by the end of the third season. In northern India the growth of the seedling ceases about November–December, the leaves commencing to fall in December ; new growth starts in February. Ordinarily the seedlings stand frost well, though severe frost sometimes affects them slightly ; in hot dry weather the new shoots of young plants are apt to dry up, but the seedlings have good power of recovery from such injury.

SILVICULTURAL CHARACTERS. The tree is a light-demander, developing best in open situations ; experiments carried out at Dehra Dun have shown that under even partial shade its development is poorer than in full sunlight, while in the wild state it is typically found in open places. It is decidedly frost-hardy ; in the abnormal frosts of 1905 in northern India, and 1910–11 in the Peninsula, it proved to be one of the hardiest trees. It also stands drought well, as was proved in the severe drought of 1899 and 1900 in central India, when it was unaffected : in the abnormal drought of 1913–14 in central India, however, it is said not to have flowered and fruited, while seedlings of the previous year died in quantity. It has great power of recovery from injury of any kind, including fire, and thrives in grassy tracts which are burnt annually. It is readily browsed by goats and is a good camel fodder ; even in heavily grazed areas, however, the dense prickly clumps protect not only themselves but also other tree seedlings and saplings, enabling them to establish themselves. In its tree form its dense spreading crown affords a considerable degree of shade, killing out grass and other vegetation underneath it. It coppices and pollards well and produces root-suckers. Measurements made by Mr. C. M. McCrie in Gorakhpur, United Provinces, in 1910 showed an average number of shoots per stool of 2·09, 1·42, and 1·16 for coppice 1, 5, and 7 years old respectively: often, however, it coppices a good deal more freely than this. It is more prone to the attacks of the dodder (*Cuscuta reflexa*, Roxb.) than any other tree, and may frequently be seen covered with this parasite as with a thick yellow net.

NATURAL REPRODUCTION. The wild fruits are greedily devoured by jackals, pigs, bears, and other animals, the stones appearing in quantity in their excreta, and also by peafowl, pigeons, and other birds, whose crops may be found full of fruits swallowed whole: in this way the seed is scattered widely. If the fruits fall on the ground the outer fleshy portion rots off or dries up and is eaten by white ants or other insects, the hard stone remaining intact. Numerous tests carried out in order to determine the factors which govern the germination of the seed and development of the seedling under natural conditions have shown that fruits or stones which become partially or wholly buried by rain showers or other causes have no difficulty in germinating during the first half of the rainy season, in which case the seedling has little trouble in establishing itself. Fruits or stones which lie on the surface of the ground may germinate to some extent, but in this case the seedlings very often perish before they can establish themselves. The advantage of a loose soil, in which the fruits become readily buried between the time when they fall in the cold or early hot season and the commencement of the monsoon, is thus apparent. Another factor of great importance is that the stones should lie in soil exposed to the sun, since those lying in any but partial shade persistently refuse to germinate, and even those in slight shade show very little tendency to do so. Not only was this observed in various shaded and unshaded plots in the open, but fruits sown in a box kept under shade and regularly watered refused to germinate although fruits otherwise similarly treated but exposed to the sun germinated readily; eventually the shaded box was placed in the sun, and germination started within a few days. Under natural conditions the fruits or stones lie on the ground throughout the hot weather and germination does not commence till the rainy season. Some of the seed which fails to germinate during the first rains may do so the following year. Abundance of light is essential for the proper development of the young plants; at Dehra Dun a plot of seedlings which had established themselves under natural conditions and were growing well were in their third year overshadowed by faster growing saplings of other species in an adjoining plot, with the result that their development was checked and several of them were killed.

The abundant fruit crop, the protection afforded to the seeds by the hard stone, the demand for an abundance of sunlight, and the hardiness of the seedlings explain to some extent the profusion with which natural reproduction springs up on open lands.

ARTIFICIAL REPRODUCTION. The tree may be raised artificially by direct sowing or by transplanting seedlings or root-suckers. Propagation by cuttings has been tried without success. In the case of direct sowing the fruits, preferably deprived of the fleshy portion or else thoroughly dried, may be sown about a month before the commencement of the rains, either broadcast on ploughed land or along lines which have been ploughed or dug up ; if quick growth is desired during the first few years the latter is preferable, since weeding can be more cheaply and effectively carried out. After sowing, the fruits should be covered with earth to a depth not exceeding ½ in. In Berar the tree has been raised successfully by line sowings in combination with field crops, and this would seem to be the most efficient and economical method of raising it artificially for afforestation purposes, provided that the lines of seedlings are kept free from suppression by the crops.

For transplanting purposes the fruits, deprived of their fleshy covering or well dried, should be sown in seed-beds, either broadcast or in drills, in February or March and covered with earth to a depth of ¼ to ½ in. The beds should be situated in the open, fully exposed to the sun, and watering and weeding should be carried out regularly. The seedlings commence to appear as a rule during the hot weather, and continue appearing until the first month or two of the rains. The seedlings may be transplanted either during the first or during the second rainy season, but owing to the long taproot it is preferable to prune the stem down to about 2 in. and the taproot down to about 6 in.; the plants survive this treatment well, and soon commence to shoot up. During the first rains with reasonable care transplanting may be done with unpruned plants ; the plants may die down partially, but as a rule they recover next year. The cultivated variety is usually propagated by ring grafting on stocks of the wild form. Plants of the latter, about three years old, are pollarded or coppiced in the cold season, and grafting is carried out on a few of the resulting shoots, the remainder being pruned down. Rings of bark about ¾ in. long, including a bud, are taken from the variety which it is desired to propagate and fitted exactly on to corresponding positions on the wild stock from which similar rings of bark have been removed, the whole being bandaged and covered with clay.

Rate of growth. In open situations the growth is often fast. Gamble's specimens showed 4 to 6 rings per inch of radius, representing a mean annual girth increment of about 1 to 1·6 in. Measurements made in 1910 by Mr. C. M. McCrie in coppice coupes in Gorakhpur, United Provinces, gave the following results :

Age 1 year, mean height 2 ft. 5 in.
„ 5 years, „ „ 7 ft. 2 in.
„ 7 „ „ „ 8 ft. 3 in.

Figures recorded in the Punjab Forest Conference Proceedings of 1913–14 of measurements in seven different experimental coupes in the Jhelum and Chenab forest divisions showed an average height-growth during the first season varying from 2 ft. to 5½ ft. ; the felling was done at different times from March to July, but the results proved nothing definite as to the best month for coppicing.

2. **Zizyphus Xylopyrus**, Willd. Vern. *Kat-ber, bhander, chitena, ghat-bor*, Hind. ; *Goti*, Hind., Mar., Tel. ; *Kottei*, Tam.

A small deciduous tree or large shrub with straggling branches, the branchlets armed with prickles, or often unarmed, especially in the case of old trees or on good soil : bark greyish brown, smooth, or rough with small oblong exfoliating scales. The wood is used for agricultural implements, fuel, and charcoal. The bark is used for tanning; the fruits are rich in tannin, and are employed for tanning and for dyeing leather black. The leaves are used for fodder. One of the chief uses of the tree, however, is for the propagation of lac. It is a useful tree for clothing certain types of poor dry ground or clay soil where little else will grow.

DISTRIBUTION AND HABITAT. Sub-Himalayan tract and outer hills up to 3,000 ft. from the Sutlej eastwards, Bihar, Chota Nagpur, Rajputana, central and southern India, the Deccan and the Peninsula generally: also in the dry parts of Ceylon. Talbot says it ascends to 4,000 ft. in the Nasik *ghats*, and Bourdillon says it is found everywhere in the sub-alpine deciduous forests of Travancore. It is a very common tree in certain types of dry open deciduous or scrub forests, sometimes on clay soil but also on soil composed of sand and boulders, on hilly, undulating, or flat ground: it is often gregarious, and is frequently associated with *Zizyphus Jujuba* and *Acacia Catechu*, or with *Gardenia turgida*. It occurs frequently on open grass-lands, often forming impenetrable thickets when young, and in the sub-Himalayan tract it springs up in blanks in the sal forests. Fig. 85 shows a typical pure patch. In its natural habitat the absolute maximum shade temperature varies from 100° to 118° F., the absolute minimum from 30° to 60° F., and the rainfall from 20 to 75 in.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The old leaves fall about February–March and the new shoots and leaves appear in April–May, the small clusters of green flowers appearing in the axils of the young leaves on the new shoots from April to June. The young fruits begin to form soon after flowering, and in northern India are full grown but still green by the end of the rains or soon after, becoming fully ripe about January to April next year. The fruit (Fig. 88, *a*) is a globose drupe about 0·75–1 in. in diameter, at first green, turning brown when thoroughly ripe, the fleshy portion dry and mealy, not edible, enclosing a hard stone which is two- or three- (rarely four-) celled, each cell containing one seed, though there are rarely more than two fertile seeds in each fruit. The fruits may hang some time on the tree before falling. The seed within the stone retains its vitality to some extent for 2½ years from the time of ripening, but tests have shown that at any time the proportion of fertile seed is comparatively low, and that it decreases the longer germination is postponed.

GERMINATION (Fig. 88, *b*. *c*). Epigeous. Under natural conditions the seed may germinate either within the stone of the fruit or after it has escaped through the splitting of the stone. The former is perhaps more usual. The stone splits generally in two or three places, portions of the hard shell falling away in the form of valves: as soon as splitting takes place the round green long-stalked leafy cotyledons emerge, leaving the testa inside, and the radicle descends. It is a common occurrence to find two seedlings appearing from one stone, while occasionally three seedlings appear. If the fruit is buried the two cotyledons appear above ground some little distance apart, and the plumule does not emerge for some time after.

THE SEEDLING (Fig. 88).

Roots: primary root long, thin to moderately thick, terete, tapering, wiry: lateral roots numerous, fine, fibrous, distributed down main root. *Hypocotyl* distinct from root but very short, subterranean or only just appear-

0

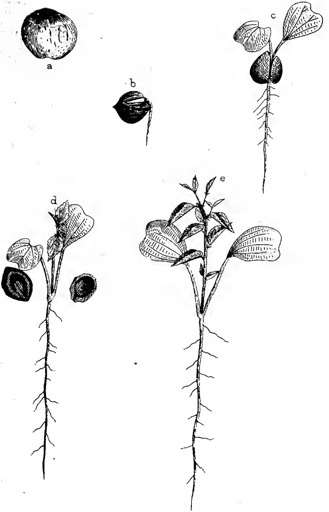

Fig. 88. *Zizyphus Xylopyrus.* Seedling × $\frac{7}{8}$.
a, fruit; *b*, *c*, germination stages; *d*, *e*, early development of seedling, first season.

ing on surface of ground. *Cotyledons*: petiole 0·9–1·2 in. long, channelled above, white turning green, minutely pubescent: lamina 0·7–0·9 in. by 0·6–0·7 in., foliaceous, somewhat fleshy, orbicular obovate, truncate or retuse, base sub-cordate, entire, dark green, glabrous, prominently 5-veined from near base, subsidiary veins reticulate. *Stem* erect, terete, somewhat zigzag at nodes, wiry, tomentose; internodes 0·15–0·4 in. long. *Leaves* simple, first pair usually opposite or sub-opposite, smaller than the others, remainder alternate. Petiole 0·1–0·15 in. long, tomentose. Lamina, first pair 0·2–0·3 in. by 0·15 in., subsequent leaves 0·5–0·7 in. by 0·3–0·4 in., ovate, acute, mucronate, serrate, glabrous or slightly pubescent above, pubescent below

The height-growth of the seedling is slow, but at an early age—often in the first month after germination, when the height is not more than 1–1½ in.—prickly side branches are sent out, and these develop more rapidly than the main stem. By the end of the first season the seedlings are only a few inches high, with numerous side branches up to 6 or 7 in. in length; a long wiry taproot, often 15 in. long by the end of the first season, is produced. The cotyledons persist until the end of the first season, and sometimes through the greater part of the cold weather, before they die off. The subsequent height-growth of the seedling is slow, a height of about 9–15 in. being ordinarily attained by the end of the third season: the branch development, however, is vigorous, and in a few years the young plants form a dense impenetrable thorny thicket. In northern India the leaves of seedlings commence to dry up about November–December and fall from January to March, the plants being leafless until the new shoots and leaves appear from March to May. The leaves are much subject to defoliation by insects. The seedlings are decidedly frost-tender and are apt to die off on damp ground; they withstand drought well. Although weeding stimulates their development they have considerable power of struggling up through a comparatively heavy growth of grass.

SILVICULTURAL CHARACTERS. The tree is a light-demander, growing typically in open situations, but is capable of standing a slight degree of shade. It withstands drought well; in the abnormal drought of 1907 and 1908 in Oudh it suffered slightly, but this was on poor dry soil where most species would have succumbed. It is frost-tender in its younger stages, and is usually considered to be tender to frost in its later stages also. It suffered considerably in the Saharanpur district in the abnormal frost of 1905, though in the neighbouring Lansdowne forest division it is reported to have been one of the last trees affected. It is readily browsed by goats. It has considerable power of recovery from injury, and is thus capable of surviving in areas overrun by fire. It coppices and pollards well. Measurements made in 1910 by Mr. C. M. McCrie in coppice coupes in Gorakhpur, United Provinces, showed an average production of 1·5 to 3 shoots per stool in coppice 5 to 9 years old and 1 shoot per stool in coppice 11 to 15 years old. In grassy tracts the tree tends to kill out the grass underneath it, particularly where it forms thickets.

NATURAL REPRODUCTION. The fruits fall at different times after ripening, during the cold and hot seasons. If they become buried by rain or otherwise, germination frequently takes place during the first rainy season, the stone and the outer covering, if present, splitting as already described. Many fruits, however, lie through the rains and succeeding cold and hot seasons and do not germinate until the second rains, and instances have been noticed where germination has not taken place until the third rains. Where the fruits lie on the ground for some time the outer soft portion is usually eaten off by white ants or rots off, the hard stone being left, and where the stones lie on the surface of the ground exposed to the sun they often split in the hot weather, the seed escaping and germinating separately. Natural reproduction is often plentiful on grass-lands and other open places; it does not appear under heavy shade. Its establishment is facilitated through the protection offered by the dense straggling thorny growth of the young plants, and their capacity for persisting on poor dry ground, recovering from injury, and struggling through grass.

Artificial reproduction. In order to raise plants in the nursery the stones, divested of their outer covering to hasten germination, should be sown in drills in March or April and covered with earth to a depth of ¼ to ½ in. Copious watering stimulates germination, but after germination takes place water should be given more sparingly, otherwise the seedlings are liable to rot. The seed-beds should be fully exposed to the sun. Under these conditions germination ordinarily takes place at different times during the first rains if fresh fruits be used; some fruits may, however, lie without germinating till the second season. If fruit-stones which have lain ungerminated for a year round the trees are collected and sown, germination takes place earlier than in the case of fresh fruits. The seedlings may be transplanted during the first rains. Transplanting during the second rains with pruned stem and roots has not been tried, but it may possibly succeed as in the case of *Z. Jujuba*. This is one of the species which have been raised in direct sowings along with field crops in Berar.

Rate of growth. The rate of growth of seedling trees is slow, but that of coppice-shoots is fairly rapid. Measurements made in 1910 by Mr. C. M. McCrie, in coppice coupes in Gorakhpur, United Provinces, showed the following rate of growth of *Zizyphus Xylopyrus* as compared with sal in the same coupes:

Zizyphus Xylopyrus: coppice measurements, Gorakhpur, United Provinces.

	Mean height.		Mean girth.	
Age.	*Zizyphus Xylopyrus.*	Sal.	*Zizyphus Xylopyrus.*	Sal.
years.	ft.	ft.	in.	in.
2	4·8	3·0	1·2	—
4	8·2	7·0	2·2	2·0
6	11·0	10·3	3·0	2·9
8	13·2	13·0	3·7	3·8
10	15·2	15·3	4·2	4·8
12	16·8	17·5	4·6	5·8
14	18·3	19·2	5·0	6·7
16	19·3	20·9	5·3	7·5

Measurements made in the Bhandara district, Central Provinces, in 1912–13 showed an average height of coppice-shoots one year old to be 6 ft. 9 in. for *Zizyphus Xylopyrus*, as compared with 7 ft. 5 in. for *Phyllanthus Emblica*, 7 ft. 1 in. for teak, 6 ft. 4 in. for *Acacia Catechu*, and 3 ft. 11 in. for *Buchanania latifolia*. In the Madras Forest Administration Report of 1907–8 it is recorded that coppice-shoots six months old in the Chingleput district had a height of 8 to 15 ft. and a girth of 4 in.

3. **Zizyphus vulgaris**, Lam. Vern. *Sinjli*, *simli*, Punjab.

A large shrub or small tree with edible fruit, wild in the Punjab and North-West Frontier Province from the Ravi to the Indus, ascending to about 6,000 ft. in the outer Himalaya and growing well on dry gravelly soil; it is cultivated in the Punjab, Kashmir, Baluchistan, and other places as well as in southern Europe, where it has run wild.

In Hazara it is commonly planted round villages in the lower hills up to 6,000 ft., and grows well on dry rocky ground. It has remarkable capacity for producing root-suckers, which form dense thickets, and by means of which it spreads over bare hill-sides (see Fig. 89): for this reason it is an excellent species for afforesting dry or unstable slopes.

An experiment in afforesting a bare hot slope was started in the North-West Frontier Province in 1909–10 by planting root-suckers of this species, about 500 in the rains and a similar number in December: the former all died, but nearly all the latter sprouted, though only about 25 per cent. survived the hot weather. In favourable years planting in the winter would probably be successful. The fragrant flowers appear in May (Hazara).

4. **Zizyphus nummularia**, W. and A. Syn. *Z. microphylla*, Roxb. Vern. *Bal. malla*, Pb.; *Jangra*, Sind.

A gregarious prickly shrub of the dry and arid regions of the Punjab, Sind, Baluchistan, Rajputana, and the Indian Peninsula, often flourishing on clay or black cotton soil. The fruits, which ripen in the cold season, are edible, and are devoured by jackals, which spread the seeds. The plant produces root-suckers freely and forms dense thorny clumps.

5. **Zizyphus Oenoplia**, Mill. Syn. *Z. Napeca*, Roxb. Vern. *Makai*, *makoh*, Hind.; *Irони*, C. P.; *Purgi*, Kan.; *Tawzinwè*, *sudauk*, Burm.

A prickly straggling shrub or climber, common throughout the greater part of India and Burma. The flowers appear from April to July and the fruits ripen in the cold season. This climber is a most troublesome pest in some localities, particularly in the Central Provinces, where it forms dense impenetrable masses, hindering forest operations and preventing the proper development of the trees. Mr. J. W. Best,[1] writing of this pest in the Bhandara division, Central Provinces, notes that it is particularly prevalent wherever heavy grazing has taken place, as other species which are not protected by nature from grazing tend to disappear and make way for this climber. Where on the other hand the forest growth is dense and grazing has been excluded for many years the climber is comparatively rare. Evidence in Chanda points to the fact that the climber has increased enormously owing to fire-protection. Experiments have been undertaken with the view of ascertaining what steps are possible to eradicate it or to keep it under control, and a certain amount of success has been attained in Chanda by cutting it down and then burning the area annually for a series of years; after five years of burning it was found that the pest had visibly decreased except in open places. The climber is a strong light-demander, and any possible means of increasing the density of the growing stock would tend to keep it down. In Bhandara experiments for ascertaining the best means of eradicating it have comprised: (*a*) cutting the climber at a height of 1 ft. from ground-level and then admitting grazing;

---

[1] Ind. Forester, xxxv (1909), p. 610.

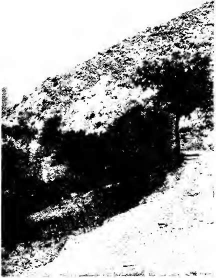

FIG. 89. *Zizyphus vulgaris*, tree, on right, with dense growth of root suckers below the road, Hazara, 4,000 ft.

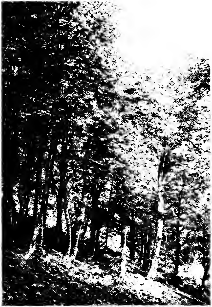

FIG. 90. *Aesculus indica* growing gregariously in a moist ravine, 7,500 ft., Kagan Valley, Hazara.

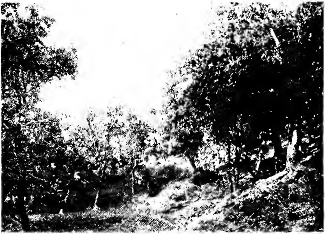

Fig. 91. *Acer caesium* growing gregariously in an open glade at 8,000 ft., Hazara

Fig. 92. *Schleichera trijuga* trees, Siwaliks, United Provinces

(*b*) cutting it and then burning; (*c*) cutting it, splitting the stump and keeping the split open by means of a stick or stone; (*d*) cutting it, splitting the stump, and pouring on the exposed surface, particularly on the cambium layer, a solution of quicklime and sulphur in the proportion of 4 oz. of the former to 1 oz. of the latter in 4 lb. of water, the whole being well boiled. According to the latest report available the application of lime, sulphur, and boiling water is said not to have been very successful: splitting the stumps of the cut climber is reported to have given better results.[1]

6. **Zizyphus rugosa**, Lam. Syn. *Z. latifolia*, Roxb. Vern. *Suran, churna, bhand ber, dhaura*, Hind.; *Turan*, Mar.; *Churai*, Tam.; *Myaukzi*, Burm.

A scrambling or climbing large shrub or small tree armed with strong hooked prickles, common in many parts of India and Burma. This plant is at times troublesome, but is far less so than *Z. Oenoplia*.

ORDER XX. SAPINDACEAE

An order of considerable interest and importance in Indian forestry.

Genera 1. ACER, Tournef.; 2. DODONAEA, Linn.; 3. AESCULUS, Linn.; 4. SCHLEICHERA, Willd.; 5. SAPINDUS, Linn.

1. ACER, Tournef.

There are about fifteen species of maple in India, all trees of the hills: of these only two are non-Himalayan, one (*A. isolobium*, Kurz) being confined to Burma and the other (*A. niveum*, Blume) to Assam and Burma, while of the Himalayan species two (*A. oblongum*, Wall., and *A. laevigatum*, Wall.) extend to Assam or Manipur, and a third (*A. Thomsoni*, Miq.) to Assam, Manipur, and Burma. Of the Himalayan species three (*A. pentapomicum*, J. L. Stewart, *A. villosum*, Wall., and *A. caesium*, Wall.) occur in the western region; six (*A. Hookeri*, Miq., *A. sikkimense*, Miq., *A. stachyophyllum*, Hiern., *A. Thomsoni*, Miq., *A. Papilio*, King, and *A. Campbellii*, Hook. f. and Thoms.) in the eastern region; and four (*A. oblongum*, Wall., *A. laevigatum*, Wall., *A. caudatum*, Wall., and *A. pictum*, Thunb.) in both regions. Hitherto the Indian maples have not possessed the economic importance of those of most other countries in which maples are found. This is not due to any inferiority in the quality of the wood, for according to Gamble the structure of the wood of all maples, Indian included, is very uniform, and most if not all Indian species possess the handsome silver-grain characteristic of maple wood in general. That the wood of Indian maples has so far been restricted almost entirely to local use is due mainly to the fact that the trees are found chiefly in mountainous country from which extraction is difficult, that the wood is not durable enough for general construction on the plains, and that the demand for woods of its class for joinery or ornamental work can be met by other woods in more accessible regions. Locally the wood of maples is used for planking, tea-boxes, and construction, and for turning into drinking-cups and other utensils. With improvements in methods of extraction and with the development of wider markets the Himalayan maples may yet become of greater economic importance than is the case at present, in which event more attention will have to be paid to their silvicultural study than has been found necessary in the past. Silviculturally some of the maples are of local importance in restocking open spaces, as their reproduction by seed is usually good. They are easily raised from seed sown in nursery beds in the spring, transplanting being best done in the winter. The maples as a rule coppice well and produce root-suckers; they are fairly immune from damage by browsing.

---

[1] Forest Report, C. P., 1916–17.

Species 1. *A. oblongum*, Wall.; 2. *A. laevigatum*, Wall.; 3. *A. pentapomicum*, J. L. Stewart; 4. *A. caesium*, Wall.; 5. *A. villosum*, Wall.; 6. *A. pictum*, Thunb.; 7. *A. Campbellii*, Hook. f. and Thoms.; 8. *A. sikkimense*, Miq.

1. **Acer oblongum**, Wall. Vern. *Pangoi*, *parpat*, *kirmola*, W. Him.

A moderate-sized tree of the outer Himalaya and valleys from the Jhelum to Bhutan, ascending to 6,500 ft., Assam, Manipur. It is essentially a low-level species, being found both on the outer hill slopes of the Himalaya, for example below Mussoorie, and in ravines or moist valleys, as along the banks of the Kotri river in the United Provinces at 2,000 ft., and in some parts of the Dehra Dun valley below 2,000 ft. The leaf differs from the ordinary type of maple leaf in not being lobed, but oblong lanceolate and entire. The tree is never quite leafless; the new shoots and leaves, which are glossy, reddish brown or pale yellowish green, appear in March–April, and the old leaves fall soon after. The flowers appear with the young leaves, and the fruits ripen next cold season, hanging some time on the trees: the winged fruit is the usual double samara characteristic of maples in general. The tree is sometimes planted for ornament. It is easily raised from seed sown in beds about March, the seedlings being pricked out in the nursery during the first rains and transplanted either in the rains following or in the cold season. The seedlings bear transplanting well. It is unnecessary to prune the roots and stem except in the case of large plants: they survive the operation, but subsequent growth for a year or two is not so rapid as in the case of unpruned plants. The growth of young plants is fairly rapid. Plants raised at Dehra Dun showed the following height-growth during the first four seasons:

1st season . . .	height 6–12 in.
2nd season . . .	maximum height 3 ft. 6 in.
3rd season . . .	maximum height 5 ft. 9 in.
4th season . . .	height 2 ft. 1 in. to 10 ft. 7 in.

On stiff ground the plants develop badly; good drainage and porous soil are required to promote the best growth. Weeding also has a marked effect on the development of the seedlings and saplings. The tree coppices vigorously, the shoots growing rapidly. Gamble's specimens showed the growth of the tree to be moderate, namely 7 rings per inch of radius or a mean annual girth increment of 0·9 in.

2. **Acer laevigatum**, Wall. Vern. *Putli*, Nep.

A tree larger than *A. oblongum*, but with leaves somewhat similar in shape. It occurs in the Himalaya from the Jumna eastwards at 5,000–9,000 ft., being commoner in the east than in the west; also in the Khasi hills.

3. **Acer pentapomicum**, J. L. Stewart. Vern. *Trekhan*, *teon*, W. Him.

A small or moderate-sized tree of the western Himalaya in the Punjab and Kashmir, from 2,500 to 7,000 ft. in the inner dry valleys, where it is almost gregarious in hot dry situations associated with *Quercus Ilex* and *Fraxinus xanthoxyloides*. In the Jhelum valley it descends below 2,000 ft. It is common on the banks of dry ravines at low elevations in the Hazara district.

4. **Acer caesium,** Wall. Vern. *Barakainju, trekhan, mandar*, W. Him.

A large tree, attaining a girth of 10 ft. or more: the largest maple of the western Himalaya. Leaves 5-lobed, broader than long, usually glaucous beneath.

DISTRIBUTION AND HABITAT. Western Himalaya from Nepal westwards, chiefly at 7,000–10,000 ft. but occasionally descending to 4,000 and ascending to 12,000 ft. This is the commonest maple of the western Himalaya, and is very typical of grazing grounds and open glades, where it is often more or less gregarious (see Fig. 91). It is particularly common in the forests of the Galis in Hazara, where it is in many places the most abundant broad-leaved species; here it is associated with *Abies Pindrow, Pinus excelsa, Taxus baccata, Aesculus indica, Ulmus Wallichiana, Prunus Padus*, and other trees, and often occurs in gregarious patches.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The tree is leafless in the winter, the new leaves, which are red at first, appearing from March to May. The flowers appear with the young leaves. The fruits ripen from July to October. The double samara (Fig. 93, *a*) is 1·5–2 in. or more in length.

GERMINATION (Fig. 93, *b*, *c*). Epigeous. The radicle emerges from the end of the samara opposite the wing and descends. The hypocotyl elongates, raising above ground the cotyledons enclosed in the samara; the latter falls to the ground as the cotyledons unfold.

THE SEEDLING (Fig. 93).

Roots: primary root at first moderately long, lengthening considerably later, terete, tapering, thick after the first season, at first wiry, afterwards becoming woody: lateral roots at first moderate in number and length, afterwards numerous, fibrous, distributed down the main root and most numerous towards its extremity. *Hypocotyl* 1·2–2 in. long, fusiform or tapering upwards, glabrous, tender and green or red when young, later becoming woody and greenish brown. *Cotyledons* sub-sessile, 1·1–2·2 in. by 0·3–0·5 in., foliaceous, somewhat fleshy, oblong lanceolate or ovate lanceolate, acute, base tapering, entire, green, glabrous, darker above than beneath; five parallel veins visible on under surface, the centre three more distinct than the outer two. *Leaves* simple, opposite, exstipulate. First pair, petiole 0·4–0·7 in. long, lamina 1–2·3 in. by 0·6–1·8 in., ovate, acuminate, base cordate, serrate, lobes hardly commenced forming, glabrous, green above, glaucous beneath. Subsequent leaves increasing in size and becoming more distinctly lobed; by second season regularly 5-lobed and palmately 5-veined; by third season petiole up to 2 in. long, green or reddish, lamina up to 5 in. by 5 in., central lobe acuminate, remaining lobes acuminate or acute, serrate, glabrous, paler beneath than above.

During the first two or three years the growth of the seedling amounts to only a few inches a year, but from the fourth season onwards it is more rapid, the annual growth being up to 1 ft. or more. Seedlings four years old average about 2 ft. in height and have long stout taproots. For its best development the seedling requires a porous soil free from weed-growth. It stands moderate shade for a time, but once established it requires an abundance of light. On dry ground the seedlings tend to die of drought in the first season.

SILVICULTURAL CHARACTERS. This maple is more light-demanding than *A. pictum*, with which it is sometimes associated. In youth it stands moderate but not heavy shade, while subsequently it thrives best with complete overhead light. It is not readily browsed, and in its natural habitat is frost-hardy. It produces root-suckers.

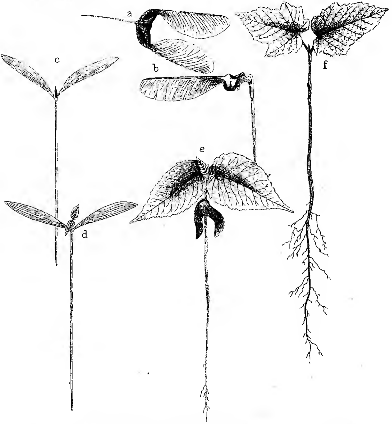

FIG. 93. *Acer caesium.* Seedling × $\frac{5}{8}$.
a, fruit; *b*, *c*. germination stages; *d*, *e*, development of seedling during first season; *f*, seedling early in second season.

NATURAL REPRODUCTION. The seed lies on the ground through the winter and germinates next spring, about April, when seedlings in all stages of germination may be found in quantity in the neighbourhood of seed-bearers.

Natural reproduction springs up in quantity on newly exposed and especially porous ground, and in places where landslips have occurred thickets of young maple may be found establishing themselves. The young plants dislike heavy weed-growth, and where this is prevalent reproduction fails. On open grazing grounds young seedlings may often be found in large quantities in the late spring or early summer, particularly where the soil is bare and loose; here the seed germinates shortly after the melting of the snow. Such places are often exposed to drought during the ensuing dry weather, and numerous seedlings perish from this cause, while grazing destroys most of the remainder, although in sheltered situations some succeed in establishing themselves.

ARTIFICIAL REPRODUCTION. Seed should be sown in seed-beds of porous soil about February or March. Germination takes place as a rule in about two to four weeks. The beds should be regularly watered in dry weather and kept free of weeds. The seedlings, which may require pricking out in the nursery, will be ready for planting out in the winter at the end of the second or third season according to size. Direct sowing has not been tried, but it would probably succeed on landslips, abandoned cultivation, or other places where the soil has been recently exposed.

RATE OF GROWTH. The growth is slow, Gamble's specimens showing 9 to 31 rings per inch of radius, or a mean annual girth increment of 0·2 to 0·7 in.

5. **Acer villosum,** Wall. Vern. *Kainju*, W. Him.

A large tree of the western Himalaya at 7,000–9,000 ft., much less common than *A. caesium*; leafless in the winter.

6. **Acer pictum,** Thunb. Syn. *A. cultratum*, Wall. Vern. *Kainchli, kilpattar*, W. Him.

A handsome moderate-sized tree, found throughout the Himalaya from the Indus to Bhutan, at 4,000–9,000 ft. Leafless in the winter, the leaves turning red before falling. It is more shade-bearing than *A. caesium*.

7. **Acer Campbellii,** Hook. f. and Th.

The commonest maple of the eastern Himalaya, occurring at 7,000–10,000 ft.; a large deciduous tree. Gamble (*Darjeeling List*) says the seedlings come up very freely self-sown, provided there is not much shade.

8. **Acer sikkimense,** Miq.

A moderate-sized tree, common in the eastern Himalaya, particularly on open spaces at 7,000–9,000 ft.

2. DODONAEA. Linn.

Dodonaea viscosa, Linn. Syn. *D. Burmanniana*, DC. Vern. *Sanatta*, Pb.; *Mehndi, banderu*, C. P.; *Lutchmi*, Mar.; *Bundu'gi*, Kan.; *Virali*, Tam.

A gregarious evergreen shrub or small tree, the young shoots viscid with a yellow resin. It is locally abundant in the dry parts of the western Himalaya from the plains up to 4,500 ft., occurring sporadically up to 6,500 ft. on hot aspects (e. g. Simla hills), Sind, Baluchistan, and the Indian Peninsula. It is planted as a hedge plant throughout the greater part of India. Besides yielding good fuel of the smaller dimensions it is a useful plant for sowing up bare slopes in suitable localities. In the *Pinus longifolia* forests of the outer Punjab hills, and in the dry miscellaneous forests below them, it is a very common undergrowth species, covering considerable areas. It is abundant over large tracts in the Deccan and in many of the drier parts of southern India, where it flourishes from the sea-coast up to 8,000 ft. in the hills, sometimes attaining the size of a small tree. Kurz says it grows on the sandy shores of Tenasserim from Amherst to Mergui; also on Narcondam island, Andamans. Regarding its occurrence in the southern forest circle, Central Provinces, Haines[1] says: 'Generally speaking it avoids trap and favours sandstone. In the Sonawani range (Balaghat) it is found on ridges of white clay schist, but is local. In Chanda it is very common and is also found there on kunker soils. In Raipur it is rare, and has not yet been noted in Nagpur-Wardha, Bhandara, or Bilaspur. It reappears on the sandstones of the Pachmarhi hills (Northern Circle).' The plant is dioecious. The season of flowering and fruiting appears to vary in different localities, the fruiting as a rule taking place in the cold and early hot season. In the outer Himalaya it flowers from January to March and the fruits ripen in the hot season, chiefly in May and June. The fruits hang in large quantities. The seeds are about 0·1 in. in diameter, nearly globose, slightly flattened, black with a hard testa; about 3,000 weigh 1 oz. The plant is usually said not to coppice: it certainly sends up numerous small shoots when cut, but possibly these do not persist. It reproduces abundantly from seed, and this, together with its capacity for growing on poor dry soils and its immunity from browsing, explains its abundance over considerable areas. It is very sensitive to fire, and is frequently killed outright when burnt, its resinous twigs burning readily.

3. AESCULUS, Linn.

Species 1. *A. indica*, Colebr.; 2. *A. punduana*, Wall.

1. **Aesculus indica**, Colebr. Syn. *Pavia indica*, Wall. **Indian horse-chestnut.** Vern. *Bankhor, pangar, kandar, gun, pu*, W. Him.; *Kakra, hán*, Kashmir; *Torjaga*, N.-W. Frontier.

A large handsome deciduous tree with a large spreading crown, drooping branches, and digitate leaves, much resembling the European horse-chestnut. Bark grey and smooth in young trees, darker and exfoliating in irregular rectangular scales in middle-aged or older trees, and in old trees often exfoliating in long narrow strips sometimes 2 ft. long, the lower extremities of which are free and the upper extremities attached to the tree, giving the bole a curious appearance as if covered with some thatching material.

Wood pale pink, soft, used for planking, boxes, and turning into cups, plates, &c. The tree attains a large size, a height of 100 ft. and a girth of 12 ft. or more being not uncommon in favourable localities.

DISTRIBUTION AND HABITAT. Western Himalaya from Nepal westwards, at 4,000–9,000 ft. usually in moist shady ravines on rich soil: frequent on northerly aspects. In moist depressions and ravines running down the hill-sides it often forms gregarious patches of varying extent (see Fig. 90). It is particularly common in the forests of Hazara, where it is associated with walnut, maple, bird-cherry, and other broad-leaved species as well as with silver fir, spruce, yew, deodar, and blue pine, though it usually occupies the depressions and moister situations, while the conifers occupy the intervening spurs. It is often planted for ornament in the hills. In its natural habitat the absolute maximum shade temperature ordinarily varies from 80° to 102° F., the absolute minimum from 25° to 10° F. or perhaps lower, and the normal rainfall from 40 to 100 in. or more.

---

[1] Ind. Forester, xxxix (1913), p. 68.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The leaves turn various shades of yellow or golden brown in September–October, and fall from October to early December. The tree often assumes a beautiful colouring in the autumn. From December to April the trees are leafless. The new leaves appear in April, the gummy outer scales and membranous inner scales of the winter buds falling with the sprouting of the new shoots. The new leaves are of a coppery red colour, and with them appear the flower buds. The large upright thyrsoid panicles of showy white flowers, tinged with red and yellow, appear from April to June, at which time the tree is extremely handsome. The fruit forms rapidly, growing in size and weight until it becomes pendulous, the stalks elongating. The fruit is an ovoid one- to three-celled leathery capsule 1·5–2 in. long, smooth, and not echinate as in the European species, containing one to three seeds 1–1·6 in. in diameter with a dark brown smooth shining fairly hard testa and a hilum about 0·5 in. in diameter (Fig. 94, *a*). About sixteen to twenty seeds weigh 1 lb. The capsules open and the seeds fall to the ground in October–November.

GERMINATION (Fig. 94, *b–g*). Hypogeous. It commences with the bursting of the testa and the elongation of the cotyledonary petioles, the thick whitish radicle emerging at an early stage and developing rapidly into a stout vigorous taproot: as the cotyledonary petioles further elongate the plumule extricates itself, the base of the young shoot being enveloped by a short tube formed by the united bases of these petioles. This elongation of the cotyledonary petioles in order to push the radicle as quickly as possible into the soil, and the rapid development of the taproot, which are also characteristic of several of the hill oaks, are contrivances for assisting the establishment of the seedling.

THE SEEDLING (Fig. 94).

Roots: primary root long, thick, almost fleshy, terete or slightly compressed, tapering, tomentose: lateral roots numerous, moderately long, thick, tomentose, distributed down main root. *Hypocotyl* not distinguishable, subterranean. *Cotyledons*: petiole 1·2–2·2 in. long, 0·4 in. broad, fleshy, flattened, pink, curved to side of stem, more or less united at the base into a short tube: laminae 1·2–1·6 in. in diameter, hemispherical, fleshy, closely cohering, outer surface rounded and depressed, inner flattened in contact. *Stem* arched during germination, soon becoming erect, slightly compressed, red turning reddish green, dotted with small whitish lenticels, glabrous or young parts minutely tomentose; internodes 3–6 in. or more in length. *Leaves* compound, opposite, exstipulate: first pair often rudimentary, trifoliate, petiole 1 in. long or less, flattened above, expanded at base, leaflets 0·3 in. long or less, linear lanceolate: second pair 5-foliate, rarely 3- or 4-foliate, petiole 0·8–1 in. long, flattened above, expanded at base, usually red, glabrous, leaflets up to 2 in. by 0·4 in., lanceolate, or oblanceolate, acuminate, serrate, glabrous, venation arcuate; subsequent leaves of first season 5-, 6-, or 7-foliate, similar in shape to second pair but becoming successively larger with number of leaflets increasing. Young leaves red, turning green after expanding.

The early development of the seedling is very rapid. The stout somewhat fleshy taproot may reach a length of 6–7 in. before the plumule emerges, but as soon as the latter appears the stem shoots up rapidly, a height of 1 ft. or more being reached within two months, the stout taproot being 1 ft. or more in length at that time. By the end of the first season a height of 2 ft. or more may be attained. The seed remains attached to the base of the plant throughout the greater part of the first season, the thick fleshy cotyledons supplying nutriment to the young plant. The seedling requires a damp situation for its best growth; in dry hot places it develops poorly and may die off. Although seedlings will persist under moderate shade for a time their growth is slow; for their best development a fair amount of light is required. A seedling only 18 in. high growing under somewhat heavy shade in Hazara was found to have fifteen annual rings. Seedlings are very readily browsed.

SILVICULTURAL CHARACTERS. The tree is a moderate light-demander, requiring a moist and slightly shady place for its early development with more light subsequently, though a considerable amount of moisture in the soil is always necessary to promote the best growth: if planted on dry hill-sides it remains stunted and unhealthy. It coppices well up to a considerable size, stumps up to 10 ft. in girth having been found to give a plentiful crop of shoots. It also produces root-suckers, particularly if the roots are cut. The tree sometimes has a pronounced twist from right to left.

NATURAL REPRODUCTION. The seeds fall in October–November, and their weight and their smooth rounded form cause them to roll into depressions, where they become covered with leaves and earth and are protected to some extent from monkeys and other animals which eat them; there they pass the winter, often under snow. Germination takes place in the following spring, commencing about April: in the case of seed lying in moist places and covered with leaves and débris, germination is successful, and the seedling rapidly establishes itself, but in drier and more open places the radicles tend to die off before germination is complete, and here the young plants are seldom able to survive. The horse-chestnut can hardly be called a gregarious tree except over restricted areas, but natural reproduction often springs up in quantity in moist ravines where conditions are favourable to successful germination and development. On moist cool slopes where the soil has been exposed by small landslips, natural seedlings are sometimes found in large numbers in loose soil among stones and boulders, which hold up the seeds.

ARTIFICIAL REPRODUCTION. The tree is not considered valuable enough to grow in forest plantations, but it is often cultivated for ornament. There is little difficulty in growing it provided dry situations exposed to a hot sun are avoided. The seeds should be collected when they ripen, in October or November, and either sown immediately after collection or stored in dry earth and sown early next year. Sowing should be done in seed-beds with good soil in a cool shady situation, the seeds being placed 6 in. apart in drills 1 ft. apart and covered with about 2 in. of earth. The beds should be weeded regularly and the soil kept loose; little watering is required. If desired the seedlings may be planted out during the first winter, but if larger plants are required they should be transplanted in nursery beds during the first winter 1 ft. apart in lines 18 in. apart, the beds being kept weeded but not watered: they should be finally transplanted during the following winter, it being unnecessary to retain earth round the roots in transplanting.

2. **Aesculus punduana,** Wall. Syn. *A. assamica*, Griff.

A tree of the Duars, Assam, and Burma, somewhat resembling *A. indica*. It is found in moist situations, especially along the banks of streams, and is very handsome with its dense spreading crown of rich green foliage, particularly when covered with the erect panicles of white flowers, which appear in February–March.

4. SCHLEICHERA, Willd.

Schleichera trijuga, Willd. Vern. *Kusam*, Hind. ; *Sagada*, Kan. ; *Pava, puvan*, Tam. ; *Gyo*, Burm. (Fig. 92.)

A large deciduous (nearly evergreen) tree with fluted comparatively short trunk and a shady spreading crown. Leaves paripinnate with two to four pairs of leaflets 2–10 in. long. Bark grey, red inside. exfoliating in irregular plates. Wood very hard, reddish brown, used for oil and sugar mills, rice pounders, agricultural implements, and other purposes. The fruit is edible and the seeds yield an oil of some value. One of the chief uses of the tree is for the propagation of lac, the quality of which is considered better than that produced on any other tree. Silviculturally the tree is useful as affording shade and protection to the soil. since it puts out its young foliage early in the hot season and gives good shade during the hottest time of the year : in the teak forests of Java it is on this account considered one of the best species to mix with the teak.

Distribution and habitat. Sub-Himalayan tract from the Sutlej to Nepal, Chota Nagpur, Central India and the Peninsula generally, and throughout Burma ; apparently absent from Assam. The tree is typical of mixed deciduous forests. often of a somewhat dry type. In the sub-Himalayan tract and outer hills it is common on well-drained boulder deposits, often occurring in quantity along the sides of ravines or along the high banks marking the edges of terraces. It is common on the south side of the Siwalik range, often on the sides of ravines on sandstone or on boulder beds. In the Central Provinces it occurs scattered in mixed forest, chiefly near the banks of streams : it is common in the Raipur district. In Burma it is common both in the upper mixed forests of the low hills and in the lower mixed forests of the plains, its spreading crown often taking up a considerable amount of room in the crop : in the lower mixed forests it grows on good alluvial loam. In general it thrives best on a light well-drained gravelly or loamy soil. In its natural habitat the absolute maximum shade temperature varies from 100° to 118° F., the absolute minimum from 30° to 60° F., and the normal rainfall from 30 to 100 in. or more.

Leaf-shedding, flowering, and fruiting. The old leaves begin to fall from December to February, turning golden yellow prior to falling, and the tree is leafless for a short time or hardly at all ; the new foliage, which is of various shades of red, turning light green and then dark green, appears in March–April. The racemes of greenish yellow flowers appear with the young leaves, some trees producing only male flowers. The fruits ripen in June–July, and quickly fall to the ground : they are globose or ovoid, 0·5–1 in. long by 0·45–0·7 in. in diameter, abruptly tapering to a point, sometimes slightly echinate, toughly coriaceous when fresh, becoming hard and brittle on drying, one-celled and one- or two-seeded (Fig. 95, *a*). The seeds are 0·4–0·6 in. by

0·35–0·5 in., irregularly ellipsoidal, slightly compressed, very oily, with a thick brown testa, enveloped when fresh in a succulent arillus of pleasantly acid taste: about forty to fifty seeds weigh 1 oz. The seed does not retain its vitality long.

GERMINATION (Fig. 95, *b–d*). Epigeous. The shell of the fruit cracks or is eaten by white ants soon after falling, the testa of the seed bursts, and the radicle emerges. The hypocotyl arches slightly, soon straightening and raising the fleshy unequal cotyledons above ground; the testa is sometimes left underground and sometimes carried up over the cotyledons, falling when these expand.

THE SEEDLING (Fig. 95).

Roots: primary root very long, moderately thick, terete, tapering, wiry, becoming woody, brown: lateral roots numerous, short to moderately long, fibrous, distributed down main root. *Hypocotyl* distinct from the root, 1·2–2·2 in. long, elliptical in section, fusiform or tapering slightly upwards, pink, tomentose in upper part, glabrescent in lower. *Cotyledons*: petiole up to 0·1 in. long, thick, flattened above: laminae one longer than the other, the apex of the former overlapping that of the latter during germination, the longer about 1 in. by 0·3 in., the shorter about 0·8 in. by 0·3 in., thick, fleshy, oblong, apex rounded, base sagittate or truncate, outer surface convex, inner concave, pale yellow or pink, glabrous. *Stem* erect, terete, green or pink, tomentose. *Leaves* compound, exstipulate, first pair or sometimes more than one pair opposite, subsequent leaves alternate, tender and usually pink to deep red when young, afterwards turning coriaceous and dark green. First pair 3-foliate, rarely 2-foliate; common petiole 0·5–0·7 in. long, terete, tomentose; terminal leaflet with petiolule 0·2–0·3 in. long, lamina 2–3·5 in. by 0·5–1 in., elliptical lanceolate, acute or shortly acuminate, base acute, margins entire or wavy, glabrous above or puberulous when young, pubescent on veins of lower surface and round margins, venation arcuate; lateral leaflets subsessile or very shortly petiolate, 1·8–2·8 in. by 0·4–0·9 in., unequally elliptical lanceolate, acute or shortly acuminate, base semicordate, margins &c. as in terminal leaflet. Subsequent leaves of first season normally 4-foliate, the rachis ending in a small bristle; terminal pair of leaflets much larger than lateral pair, the former up to 5 in., the latter up to 2 in. long. In the second year 5- or 6-foliate leaves are produced.

During the first season the growth of the seedling is comparatively slow, a maximum height of 3 to 6 in. being attained by the end of the year. The subsequent development depends largely on whether the plants are freed from weeds or not. In various experimental plots at Dehra Dun, by the end of the second season the heights attained were as follows:

(1) Weeded irrigated plots	$2\frac{1}{2}$–28 in.
(2) Unweeded irrigated plots	2–8 in.
(3) Weeded unirrigated plots	3–13 in.
(4) Unweeded unirrigated plots	$1\frac{1}{2}$–5 in.

By the end of the third season in unirrigated plots, irrigation having been abandoned, the height varied from 2 to 7 ft. where weeding was carried out, the plants being stout and vigorous, and was only 2 to 6 in. where weeding was not carried out. In northern India the growth of seedlings ceases for a time during the cold season; the leaves fall in January–February and the red new shoots and young leaves appear in February–March.

SILVICULTURAL CHARACTERS. *Schleichera trijuga* is a shade-bearer and a hardy tree as regards both frost and drought. In the abnormal droughts of 1899–1900 in the Indian Peninsula, and of 1907–8 in Oudh, it was unaffected. In its earlier stages it is very subject to damage by grazing, as cattle eat the young leaves readily. It produces root-suckers freely. Its coppicing power, though at times vigorous, appears to vary somewhat. Measurements in coppice coupes in the Rangoon division, Burma, showed an average of as many as 14 shoots per stool: on the other hand, Mr. A. E. Osmaston records the fact that of five trees coppiced in Gorakhpur, United Provinces, in 1909–10 not one produced any coppice-shoots. Other figures are given below under 'rate of growth'. Measurements in 1910 by Mr. McCrie in Gorakhpur showed 1 to 3 shoots per stool in coupes one to sixteen years old, while Mr. H. A. Gass in South Canara found as many as 18 shoots three years old on a stool. It pollards well, a fact which closely affects the cultivation of lac. Trees producing good crops of lac are those with a full round crown and not those which have grown up in a crowded crop and have badly developed crowns. In order to prepare trees for lac cultivation the crop should be opened out to some extent around them, lanky trees with badly developed crowns being heavily pollarded to induce a full crown, and any badly developed lower branches being pruned off. In the Raipur district of the Central Provinces, where lac is cultivated on this tree, two crops are obtained in the year, the *katki* crop (December–January) and the *bathri* crop (July–August); the former is usually the better. The quantity of lac produced per tree varies greatly with the size of the crown and the vigour of the shoots. An average of 30 to 40 lb. per tree per annum for the two crops is ordinarily reckoned on: trees have been known to produce as much as 180 lb. per annum. The yield of lac from *Butea frondosa* is considerably less.

NATURAL REPRODUCTION. The fruits fall towards the end of the hot season or in the beginning of the rains; the pulp and shell of the fruit soon dry up, the latter cracking or becoming eaten by white ants and the seed being washed out by heavy rain. Under natural conditions germination and the establishment of the seedling appear to depend largely on the seed becoming quickly buried in earth and débris: if this happens germination takes place not long after the fall of the fruit, but large quantities of seed perish when lying on the surface of the ground exposed to the sun. The subsequent development of the seedling, as already explained, depends on freedom from weed-growth. Much of the natural reproduction seen in the forest consists of root-suckers.

ARTIFICIAL REPRODUCTION. Experiments carried out at Dehra Dun have shown that the transplanting of nursery-raised seedlings during the second rains is attended with a good deal of failure owing to the length of the taproot. Pruning the root and stem has not yet been tried, but possibly this may result in greater success. Transplanting in the first rains is not to be recommended owing to the small size of the plants, and even at this stage the seedlings require great care in transplanting. Good results have been attained by direct sowings in well-loosened soil, the seeds being covered with earth: regular weeding for the first few years is essential. It is probable that line sowings in conjunction with the raising of field crops would prove successful.

In any form of sowing the seed requires to be sown and covered as soon after collection as possible, and grazing has to be excluded until the saplings are out of reach of cattle.

RATE OF GROWTH. The growth of seedling trees is believed to be slow to moderate, though reliable measurements are not available. The growth of coppice-shoots is fast during the first few years, becoming slower afterwards. In 1898 Mr. H. A. Gass in South Canara measured shoots three years old with a height of 16 ft., and in 1911 I measured in Gonda, United Provinces, shoots one year old with an average height of 7 ft.

The following are the results of coppice measurements in 1910 by Mr. C. M. McCrie in Gorakhpur, United Provinces, the growth of *Schleichera* being compared with that of sal :

Schleichera trijuga : coppice measurements, Gorakhpur.

Age.	Mean height.		Mean girth.	
	Schleichera.	Sal.	*Schleichera.*	Sal.
years.	ft.	ft.	in.	in.
2	4·3	3·0	—	—
4	7·2	7·0	2·2	2·0
6	9·6	10·3	2·9	2·9
7	11·8	13·0	3·6	3·8
10	13·7	15·3	4·3	4·8
12	15·2	17·5	4·8	5·8
14	16·5	19·2	5·3	6·7
16	17·5	20·9	5·6	7·5

5. SAPINDUS, Linn.

Species 1. *S. detergens*, Roxb.; 2. *S. laurifolius*, Vahl.

1. **Sapindus detergens**, Roxb. Syn. *S. Mukorossi*, Gaertn. Soapnut of northern India. Vern. *Ritha, thali*, Hind.

A large handsome deciduous tree with paripinnate leaves 8–18 in. long, with five to ten pairs of leaflets ; leaves somewhat resembling those of *Cedrela Toona*. Bark brown, exfoliating in irregular woody scales. It is not an important forest tree, but is frequently cultivated for ornament or for the sake of its fruits, the pulp of which is used as a substitute for soap.

DISTRIBUTION. Possibly indigenous in the western Himalaya from the Sutlej eastward up to 4,000 ft., Assam. Much cultivated in northern India up to 5,000 ft. in the Himalaya.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The leaves turn a rich yellow about December, falling in December–January. The trees are leafless from then until March or April, when the new leaves appear. The panicles of white or purplish flowers appear in May–June, and the fruits commence to ripen in November, remaining on the trees till January or later, the bunches of round fruits being conspicuous when the tree is leafless. The fruit (Fig. 96, *a*) is a one-seeded globose drupe, usually solitary, sometimes two drupels together. about 0·75 in. in diameter, smooth, with yellow flesh when ripennig, the flesh drying into a light brown, somewhat translucent saponaceous substance with a wrinkled surface. The seeds (Fig. 96, *b*) are smooth, black, nearly globose, about 0·5 in. long, very hard. About 350 to 400 weigh 1 lb. Tests have shown that the seed retains its vitality for one year and to a slight extent for two years.

GERMINATION (Fig. 96, *c–g*). Epigeous. It commences by the splitting of the hard covering of the seed and the emergence of the radicle, which grows rapidly downwards, the hypocotyl arching slightly until the fleshy cotyledons extricate themselves, after which the young shoot develops rapidly.

THE SEEDLING (Fig. 96).

Roots: primary root moderately long, thick, terete, tapering, whitish when young: lateral roots numerous, fibrous, distributed down main root. *Hypocotyl* distinct from and thicker than root, 1·2–1·6 in. long, thick, terete below, slightly compressed above, fusiform or tapering slightly upwards, green, glabrescent. *Cotyledons*: petiole under 0·1 in. long, thick, fleshy, flattened: lamina 0·8–1·2 in. by 0·4–0·5 in., thick, fleshy, ovate lanceolate, acute, entire, pale yellow at first, turning dark green. *Stem* erect, compressed, green, pubescent. *Leaves* compound, paripinnate or imparipinnate, exstipulate, first pair opposite, rarely alternate, subsequent leaves alternate. Rachis 2–3 in. long in earliest leaves, longer in subsequent leaves, winged. Leaflets opposite or sub-opposite, usually three pairs with a terminal leaflet in the first leaf, increasing later in first season to about five pairs with or without a terminal leaflet, 1–3 in. by 0·25–0·8 in., lanceolate, acuminate, entire, sub-coriaceous; young leaves finely pubescent, older leaves glabrous.

Where weeding and watering are carried out the growth of the seedling is rapid, a height of 6–9 in. being reached by the end of the first season and a height of 2–4 ft. by the end of the second season, by which time the taproot may attain a length of 2 ft. and a diameter of about 1 in. Where weeding and watering are not carried out the seedlings ordinarily reach a height of about 1–1½ ft. by the end of the second season. They continue growing till about November–December. The leaves turn yellow and fall about December–January, the new leaves appearing in March. The seedlings stand frost fairly well.

ARTIFICIAL REPRODUCTION. Plants raised by direct sowings, with weeding and watering, show better development than transplants. Owing to the hard covering of the seed germination is somewhat slow: if sown in April the seed does not as a rule germinate for three or four months, and sometimes not until the following year. Germination is said to be hastened by prolonged soaking in water or in moist cow-dung. If raised in seed-beds the seedlings may either be transplanted during the first rains without pruning, when they are a few inches high, or during the second rains; in the latter case the long taproot should be pruned down to about 8 in. and the stem to about 2 in. from ground-level. In either case the transplanting causes a decided check to the growth, and a certain amount of mortality may be expected. Propagation by cuttings put in during the rains has been tried with success.

2. **Sapindus laurifolius**, Vahl. Syn. *S. emarginatus*, Vahl; *S. trifoliatus*, Linn. Soapnut. Vern. *Ritha*, Mar.; *Konkudu*, Tel.; *Pungan kottei*, *nithavanji*, Tam.; *Aratala*, Kan.

A large tree of the Indian Peninsula, chiefly in southern India, much cultivated for the sake of its fruits, the pulp of which is largely used as soap. It flowers from October to December, and the fruits, consisting of two to three indehiscent carpels 0·5–0·75 in. long, with a saponaceous flesh, ripen from February to April. In southern India it is fairly common in open forests at low elevations, and in some localities the fruits form an important article of

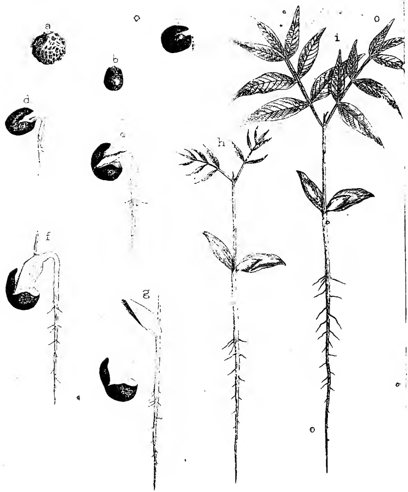

FIG. 96. *Sapindus detergens.* Seedling × ⅜.

a, fruit; *b*, seed; *c–g*, germination stages; *h*, *i*, development of seedling during first season.

minor forest produce. Talbot says that it is distributed along the Western Ghats from the Konkan southwards in evergreen monsoon forests, while the variety *emarginatus* is usually confined to the dry deciduous forests of the Deccan and Carnatic.

ORDER XXI. ANACARDIACEAE

This order contains several important forest trees, some fruit trees which are largely cultivated, and certain species which yield varnishes of commercial value: some species have acrid juice which raises blisters.

Genera 1. Rhus, Linn.; 2. Pistacia, Linn.; 3. Semecarpus, Linn.; 4. Anacardium, Rottb.: 5. Mangifera, Linn.; 6. Bouea, Meissn.: 7. Buchanania, Roxb.; 8. Melanorrhoea, Wall.; 9. Odina, Roxb.; 10. Spondias, Linn.

1. RHUS, Linn.

This genus contains several species of shrubs or small trees, important mainly as undergrowth species.

Species 1. *R. succedanea*, Linn.; 2. *R. Cotinus*, Linn.; 3. *R. punjabensis*, J. L. Stewart; 4. *R. parviflora*, Roxb.

1. **Rhus succedanea**, Linn., the Japanese lacquer tree, grows scattered throughout the greater part of the Himalayan region at 2,000–8,000 ft.

2. **Rhus Cotinus**, Linn., is found throughout the western Himalaya up to 6,000 ft., chiefly as an undergrowth species in *Pinus longifolia* forests.

3. **Rhus punjabensis**, J. L. Stewart, recognized by its large aromatic pinnate leaves, is found in the western Himalaya at 3,000–8,500 ft., usually in somewhat moist localities.

4. **Rhus parviflora**, Roxb., is a gregarious shrub or small tree which grows on bare hot slopes in the western Himalaya at 2,000–5,000 ft. and in the Pachmarhi hills and other hills of the Indian Peninsula. It is a useful plant for reclothing bare and unstable hill-sides, where, owing to its capacity for producing numerous root-suckers and its immunity from grazing, it often comes up in great profusion. Its trifoliate leaves give it somewhat the appearance of a *Desmodium* or of *Ougeinia dalbergioides*, with which it is sometimes associated: the leaves, however, are rather stiffer than those of *Desmodium* and smaller than those of *Ougeinia*. In the Himalaya the fruits ripen about June–July, when the trees are covered with the small orange-red drupes which dry before falling.

2. PISTACIA, Linn.

To this genus belongs the pistachio-nut tree, *P. vera*, Linn., a small tree of western Asia: the pistachio-nuts are imported into India from Afghanistan.

Species 1. *P. integerrima*, J. L. Stewart; 2. *P. mutica*, Fisch. and Mey.

1. **Pistacia integerrima**, J. L. Stewart. Vern. *Kakra, kakkar, kangar*, W. Him.

A moderate-sized deciduous tree with rough grey bark, viscous and aromatic when cut. Its pinnate leaves give it a superficial resemblance to the toon (*Cedrela Toona*), from which, however, it can be at once distinguished by its aromatic inner bark, while its leaves are smaller and often imparipinnate, whereas the toon has paripinnate leaves. The tree is scattered throughout the western Himalaya up to 6,500 ft., often on dry hot slopes with shallow soil. In the Punjab it is common on steep rocky ground in *Pinus longifolia* forests, and is often associated with *Acacia modesta* and *Olea cuspidata*. It is cultivated successfully in gardens on the Punjab plains. The new leaves and flowers appear from March to May, and the fruit, an oblique drupe about 0·25 in. in diameter, ripens from June to October. The young leaves and inflorescences are red, and the trees are on this account very handsome in the spring. Mr. R. N. Parker says the seed is very frequently unfertile, probably owing to the flowers being dioecious and to there being no male tree near the plant from which the seed is collected. Natural regeneration appears chiefly under the protection of bushes, through which the saplings are capable of forcing their way; afterwards, however, the tree requires light and will not stand suppression. The leaves are browsed by cattle and goats. According to Gamble the rate of growth is 8 to 9 rings per inch of radius, representing a mean annual girth increment of about 0·7 to 0·8 in. A cross-section 3 ft. 4 in. in girth in the silvicultural museum at Dehra Dun showed 96 rings, representing a mean annual girth increment of 0·42 in. The wood, which is beautifully mottled, is used for furniture and ornamental carvings, and the leaves are lopped for buffalo and camel fodder.

2. **Pistacia mutica**, Fisch. and Mey. Vern. *Khanjak*, W. Him.

A small often gregarious tree, common on dry stony hills in Baluchistan at 4,000–7,500 ft. Coppice experiments in Baluchistan showed it to possess a coppicing power varying from 15 to 100 per cent. The following measurements of coppice-shoots have been recorded in different coupes:[1]

Age in years		1	3	4	5	6	8	9	10	11	12	13
Height of coppice in feet.	Gwal forest	—	3–5	4–6	4–7	5–9	10–14	10–14	12–16	12–16	12–16	13–16
	Hazar Ganj forest	2–4	2–4	3–5	3–6							

3. SEMECARPUS, Linn.

Semecarpus Anacardium, Linn. f. Marking-nut tree. Vern. *Bhilawa*, Hind.; *Bhela*, Beng.; *Biba*, Mar.; *Gero*, *ger*, Kan.; *Shenkotta*, Tam.

A moderate-sized deciduous tree with rough dark brown bark yielding an acrid juice. The tree is recognized by its large obovate leaves and typical fruits, consisting of an oblique drupe, black when ripe, situated on a fleshy orange-coloured receptacle; the black pericarp contains a corrosive juice used as marking-ink. The tree is found scattered in the sub-Himalayan tract, chiefly in sal forest, in Bengal, Assam, Chittagong, Chota Nagpur, and throughout the greater part of the Indian Peninsula. The old leaves are shed about February–March and the new leaves appear in May. The small greenish yellow flowers appear from May to September, and the fruits ripen from December to March. The tree seeds at a very early age; seed from coppice-shoots one year old was tested and found to be fertile, and it is quite usual to see coppice-shoots two or three years old freely bearing fruits. The seedlings are rather sensitive to frost, but have good power of recovery. The tree is a moderate shade-bearer. It coppices well. Coppice measurements made in 1910 by Mr. C. M. McCrie in the Gorakhpur district, United Provinces, gave the following results for *Semecarpus Anacardium* as compared with sal :

---

[1] Annual Forest Administration Report, Baluchistan, 1915–16.

Semecarpus Anacardium : coppice measurements, Gorakhpur.

Age.	Mean height.		Mean girth.	
	Semecarpus Anacardium.	Sal.	*Semecarpus Anacardium.*	Sal.
years.	ft.	ft.	in.	in.
2	3·0	3·0	—	—
4	5·4	7·0	1·8	2·0
6	7·3	10·3	2·5	2·9
8	8·5	13·0	3·0	3·8
10	9·5	15·3	3·5	4·8
12	10·5	17·5	4·0	5·8

Measurements in 1911 in the Gonda district showed mean heights of 3 ft. and 5 ft. for coppice-shoots one and two years old respectively. Measurements in Bhandara, Central Provinces, in 1912–13 showed an average height of 4 ft. 9 in. for one-year-old coppice-shoots. As regards the rate of growth of trees, periodic measurements in six sample plots in the Siwalik, Lansdowne, Ramnagar, and Gonda forest divisions of the United Provinces showed mean annual girth increments for periods varying from 0·10 to 0·59 in.

4. ANACARDIUM, Rottb.

Anacardium occidentale. Linn. Cashew-nut tree. Vern. *Kaju*. Mar. ; *Godambe*. Kan. ; *Kolla-mavu*, Tam.

A native of South America, this tree has become established in many parts of the Indian Peninsula, particularly near the sea-coast, where it is often gregarious. It thrives best in sandy places and is important in the reclamation of sand-dunes. The flowers appear from December to April and the fruits ripen from March to June. It is used as an underwood in palmyra groves, and is best propagated by direct sowings. The wood is used for boat-building and other purposes, but the tree is best known as furnishing the cashew-nuts, which are roasted and eaten.

5. MANGIFERA, Linn.

Mangifera indica, Linn. Mango. Vern. *Ám*, Hind. ; *Amba*, Mar. : *Maá*, Tam. : *Mamidi*. Tel. ; *Mávu*, Kan. ; *Thayet*, Burm. (Fig. 97.)

A large evergreen tree with dark green coriaceous leaves and a dense rounded crown : bark thick, rough, dark grey. The mango tree is of great importance in India as a fruit tree and a shade tree for avenues and camping grounds. Its timber, which is not durable, is used for tea-boxes, packing-cases, planking, canoes, and other purposes. As a forest tree it is not of much importance, being nowhere found in great abundance.

DISTRIBUTION AND HABITAT. Probably indigenous in Burma, Assam, the Western Ghats and Satpuras, portions of the sub-Himalayan tract, Chota Nagpur, and perhaps in other localities. It is often found wild in the forest.

sometimes marking the sites of former villages and sometimes sprung from seeds discarded by man. In its natural state it affects ravines and other moist shady places. It is extensively cultivated throughout the greater part of India and Burma.

FLOWERING AND FRUITING. In southern India the flowers appear from January to March and the fruits ripen from April to July. In northern India flowering takes place from February to April, the fruit ripening in June–July. The small yellowish green flowers, in terminal panicles about 1 ft. long, are very strongly perfumed, but after maturing they lose their sweet smell and their odour becomes rather objectionable. Cultivated mangoes show great variety in size, shape, colour, and flavour: the wild fruits (Fig. 99, *a*) are about 2–4 in. long, without much flesh, but juicy and pleasantly flavoured. The seed, enclosed in a fibrous putamen, quickly loses its vitality, and requires to be sown soon after the fruit ripens. Abundant crops of fruit are not produced every year, and in some localities are produced not more than once in four or five years. Apparently climates which are too damp are unfavourable to the production of heavy crops at frequent intervals.

GERMINATION (Fig. 99. *b–d*). Hypogeous. The stout radicle emerges from the end of the seed, and the broad fleshy cotyledonary petioles elongate, enabling the young shoot to emerge. The cotyledons remain within the fibrous putamen on or below the ground.

THE SEEDLING (Fig. 99).

Roots: primary root moderately long, stout, terete, tapering, dark brown or black: lateral roots numerous, moderately thick, dark brown or black, distributed down main root. *Hypocotyl* distinct from root, 0·2–0·5 in. long, surrounded by the united decurrent bases of the cotyledonary petioles, the whole thick, fleshy, red, yellow or green, glabrous, subterranean. *Cotyledons* subterranean: petiole (free portion) 0·4–0·5 in. long, 0·25–0·4 in. broad, flattened, fleshy, curved to side of stem, united at the base to form a hypocotyledonary tube surrounding the stem: lamina 1·3–2·5 in. by 0·9–1·3 in., thick, fleshy, obliquely ovate or reniform, outer surface convex, smooth, inner flattened with a longitudinal concave groove, white, pale yellow, pink or green. *Stem* erect, terete, dark red, green or greenish red, glabrous; first internode above the cotyledons, 8–12 in., subsequent internodes 0·1–1·2 in. long. *Leaves* simple, exstipulate, first one, two, or three pairs opposite or sub-opposite, or all leaves alternate. Petiole 0·3–0·6 in. long, grooved above, glabrous. Lamina 3·5–6·5 in. by 1·1–2·2 in., oblong lanceolate, acuminate, entire, glabrous, delicate and usually coppery red in young stages, coriaceous, dark green and shining when mature, lateral veins distinct, arcuate, numerous.

The early growth of the seedling is rapid, a bare stem 8–12 in. long being formed a short time after germination; at the top of this stem the foliage leaves appear at fairly close intervals. By the end of the first season a height of 1–1½ ft. is ordinarily attained if watering and weeding are carried out, while under similar conditions a height of 2½ to 5 ft. may be attained by the end of the second season and a height of 5 to 9 ft. by the end of the third season. In northern India the season's growth ceases about November and new growth commences about March. The seedlings stand a fair amount of shade and resist slight frosts, but require protection where frost is at all severe.

SILVICULTURAL CHARACTERS. The mango tree is a shade-bearer. It prefers a deep well-drained loamy soil and a moist warm climate: if cultivated

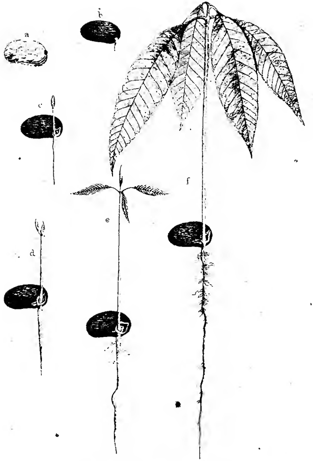

FIG. 99. *Mangifera indica.* Seedling.
a, fruit × ½; *b–d*, germination stages × ⅔; *e, f*, development of seedling during first season × ⅔.

in a dry locality it requires watering for several years, and even with special tending it does not attain the dimensions which it reaches in a moister climate. It withstands ordinary frosts, but in the abnormal frost of 1905 in northern India the mango trees suffered very severely. In the severe drought of 1907 and 1908 in Oudh the mango topes in many places were badly damaged some having been entirely destroyed: in the abnormal drought of 1899–1900 in the Central Provinces the trees were likewise killed off in considerable numbers. Gamble says that in unsuitable places young mango trees suffer from the sun, and that in southern India, as pointed out by Mr. Higgens in reference to Cuddapah topes, the bark on the western side often gets cracked by hot winds and dries up, when the white ants come and soon make a serious and unsightly wound.

NATURAL REPRODUCTION. The seeds germinate readily on the surface of the ground at the commencement of the rainy season, and the seedlings have little difficulty in establishing themselves, particularly if shaded to some extent from the sun; the ground around mango trees may sometimes be found carpeted with seedlings up to 1 ft. high at the end of the first season. Where the young plants receive protection, as in bushes, hedges, &c., mango saplings often make their way through the cover in quantity, but if exposed to the sun they die off in large numbers during the dry season.

ARTIFICIAL REPRODUCTION. In India the best varieties of cultivated mango are propagated by grafting. In Burma, however, good varieties are frequently propagated successfully from seed. For growing in avenues or topes the trees are always raised from seed, either by sowing *in situ* or by transplanting nursery-raised plants; the former method is to be recommended in preference to the latter. The pulp should be removed from the stone, and the latter should be sown as soon after ripening as possible in rich well-loosened soil. Nursery-raised plants can be transplanted without much difficulty during the first rains provided this is done fairly early, before the taproot has developed to any great extent; it is preferable, however, to raise the seedlings in baskets. During the first two or three years it is advisable to protect the young plants from frost and sun and also to water them in dry weather.

6. BOUEA, Meissner.

Bouea burmanica, Griff. Syn. *B. oppositifolia*, Meissn. Vern. *Miriam*, Beng.; *Mayan*, Burm.

A moderate-sized handsome evergreen tree with a dense crown of shiny lanceolate leaves, indigenous in the Andamans and Tenasserim and probably in the Sundarbans: much cultivated as a fruit tree in the moister parts of Burma. The fruit, which ripens about April–May, is a yellow drupe resembling a miniature mango but somewhat inferior to it in flavour. The seeds do not retain their vitality long, and should be sown quite fresh. The tree is best propagated by sowing *in situ* or by raising plants in baskets: it requires a moist climate and situation. The growth is slow.

7. BUCHANANIA, Roxb.

Buchanania latifolia, Roxb. Syn. *B. Lanzan*, Spreng. Vern. *Chiroli, pial, achar*, Hind.: *Char*, Hind., Mar.; *Morli, sara*, Tel.; *Nurkal*, Kan.; *Morala*, Tam.; *Lônbo*, Burm.

A moderate-sized tree, almost evergreen, with a straight trunk; bark dark grey or black, 0·5–0·8 in. thick, regularly divided into small rectangular plates somewhat resembling crocodile hide, reddish inside. The wood is of

poor quality, but the tree is of some economic importance for the gum and **edible fruits** which it yields. Its silvicultural importance lies in its great **abundance** in certain common types of forest and its utility for clothing **dry hills.**

DISTRIBUTION AND HABITAT. In deciduous forests throughout the greater part of India and Burma, except in the arid regions of north-western India. In the sub-Himalayan tract it occurs on the dry outer Himalayan and Siwalik slopes up to 3,000 ft. elevation, from the Sutlej to Nepal, very commonly mixed with the small-sized sal of these hills or with *Anogeissus latifolia* and extending at times into the lower limits of *Pinus longifolia*. It is also common in the drier types of sal forest in the sub-Himalayan tract outside the hills and in the Indian Peninsula, where it is also abundant in mixed deciduous forests, particularly of the drier types. It is often found in abundance on clayey soil. In Burma it is characteristic of dry open forests and is particularly common in *indaing* forest on laterite soil, associated with *Dipterocarpus tuberculatus, Pentacme suavis, Shorea obtusa*, and *Melanorrhoea usitata*: it extends into the deciduous forests of the dry zone of Upper Burma. In Travancore it is very common in all deciduous forests up to 4,000 ft. (Bourdillon). In its natural habitat the absolute maximum shade temperature varies from 105° to 115° F., the absolute minimum from 30° to 55° F., and the normal rainfall from 30 to 85 in.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The tree is leafless or nearly so for a very short time during the hot season. The pyramidal panicles of small greenish white flowers appear from January to March and the fruits ripen from April to June. The fruit is an ovoid drupe about 0·5 in. long, black when ripe, with a hard two-valved stone 0·35–0·4 in. in diameter (Fig. 100, *a*) enclosing an oily seed; about 100–120 stones weigh 1 oz. Tests carried out at Dehra Dun with seed stored in an air-tight tin for one year showed a fertility of 50 per cent. It was found, however, that seed exposed to the sun soon lost its vitality. Fresh seed was found to have a fertility of about 70 per cent.

GERMINATION (Fig. 100, *b–e*). Epigeous. It commences with the splitting of the fruit-stone into two equal valves, the radicle pushing its way through the opening; the hypocotyl arches slightly, withdrawing the fleshy cotyledons from the stone and raising them above ground, the valves of the stone remaining on or under the ground.

THE SEEDLING (Fig. 100).

Roots: primary root long, thick, terete, tapering, somewhat delicate in texture for a time: lateral roots moderate in number, fibrous, distributed down main root. *Hypocotyl* distinct from the root, 1·5–2 in. long, terete, tapering upwards, green, pubescent. *Cotyledons*: petiole 0·1 in. long or less, flattened above, pubescent: lamina 0·3–0·35 in. by 0·2–0·25 in., thick, fleshy, elliptical, apex rounded, base contracted, outer surface rounded, inner flattened, green, glabrous. *Stem* erect, terete, pubescent; internodes 0·2–0·7 in. long. *Leaves* simple, exstipulate, first pair or sometimes two pairs opposite, subsequent leaves alternate. Petiole 0·1–0·15 in. long, flattened above, pubescent. Lamina 1·5–2·8 in. long, ovate or elliptical, obtuse or acute, base acute or rounded, entire, dark green above, paler beneath, glabrous above, pubescent on principal veins beneath and on margins, lateral veins 8–16 pairs, slightly impressed on upper surface.

The development of the seedling is slow, even under favourable conditions.

By the end of the first season, even if regular weeding is carried out, the plants do not ordinarily attain a height of more than 3 in. Watering appears to have little effect on the growth, and during the first season the seedlings develop fairly well in a moderate growth of grass and weeds : subsequently, however, weeds tend to hamper their growth or to kill them out. If regular weeding is carried out maximum heights of 18 in. and 4½ ft. may be attained by the end of the second and third seasons respectively, but on unweeded ground the growth is considerably slower. The seedlings are very sensitive to frost, particularly on grass-covered ground : they are also sensitive to drought and are subject to insect attacks. They require well-drained ground, as the roots tend to rot off in water-logged soil.

SILVICULTURAL CHARACTERS. The tree is a moderate light-demander. It is very sensitive to frost, and somewhat sensitive to drought, having suffered considerably in the abnormal drought of 1899 and 1900 in the Central Provinces. It is not readily browsed. Silviculturally it is a useful tree for clothing dry hill-sides within its natural region. It avoids water-logged ground. It produces root-suckers and coppice-shoots, though its coppicing power varies. Mr. A. E. Osmaston[1] records that, in experiments in the Gorakhpur forests in 1909–10, of 26 trees coppiced only 4 per cent. of the stools produced shoots. These experiments were, however, conducted after abnormal seasons of drought which may have affected the vigour of the stools. Measurements in the same forests by Mr. C. M. McCrie in 1910 showed an average varying from 1 to 3·58 shoots per stool in coupes 1 to 16 years old. In the Gonda district. United Provinces, in 1911 I found the average to be 2·2 and 1·5 shoots per stool in coupes 1 and 2 years old respectively.

NATURAL REPRODUCTION. The fruits fall immediately before or at the commencement of the rainy season. If they are quickly covered with earth or débris by the rain, or are protected by grass or other low cover, germination soon commences and the seedlings have a chance of establishing themselves, developing slowly. Seeds lying on the surface of the ground exposed to the sun either fail to germinate and soon lose their vitality or, if they germinate, the radicles tend to dry up ; much mortality is caused in this way. Another fruitful cause of mortality is the destruction of the radicle by insects. Under favourable conditions natural reproduction appears in quantity, almost gregariously in places ; part of the natural reproduction found in the forest consists of root-suckers, particularly on hilly ground and where the roots are liable to be exposed.

ARTIFICIAL REPRODUCTION. Care should be taken not to collect seeds which have lain on the ground exposed to the sun for any time, as these have a low percentage of fertility. Experiments at Dehra Dun have shown that direct sowing is more successful than transplanting from nursery beds, whether the latter is carried out during the first or the second rains, and whether the taproot and stem are pruned down or not. This species has been raised with others in line sowings in conjunction with the cultivation of field crops in the Amraoti district, Berar.

RATE OF GROWTH. Available statistics show that the rate of growth of seedling trees is slow. Periodical measurements of ninety-seven trees in sample plots in the submontane tract of the Saharanpur Siwaliks gave the following **rate of growth** :

---

[1] Ind. Forester, xxxvii (1911), p. 429.

Buchanania latifolia : rate of growth in sample plots, Siwaliks.

Age.	Girth.	Age.	Girth.
years.	ft. in.	years.	ft. in.
40	0 5	140	2 0
60	0 8	160	2 6
80	1 0	180	3 0
100	1 4	200	3 6
120	1 8	220	4 0

Measurements in six sample plots in the Lansdowne and Ramnagar forest divisions of the United Provinces showed mean annual girth increments varying from 0·07 to 0·56 in. In the Bhira range, Kheri, United Provinces, sample plot measurements showed periodical mean annual increments of 0·56 in. for two trees 2–3 ft. in girth, and 0·12 in. for one tree 3–4 ft. in girth. A cross-section 3 ft. 2 in. in girth in the silvicultural museum at Dehra Dun showed 43 rings, representing a mean annual girth increment of 0·88 in.

As regards coppice, measurements made in 1910 by Mr. C. M. McCrie in Gorakhpur, United Provinces, gave the following results for *Buchanania latifolia* as compared with sal :

Buchanania latifolia : coppice measurements, Gorakhpur.

	Mean height.		Mean girth.	
Age.	*Buchanania latifolia.*	Sal.	*Buchanania latifolia.*	Sal.
years.	ft.	ft.	in.	in.
2	4·7	3·0	—	—
4	8·0	7·0	2·8	2·0
6	10·2	10·3	3·7	2·9
8	11·8	13·0	4·6	3·8
10	13·1	15·3	5·1	4·8
12	14·2	17·5	5·5	5·8
14	15·0	19·2	5·7	6·7
16	15·8	20·9	5·9	7·5

Coppice measurements in Gonda, United Provinces, in 1911 showed a mean height of 4·2 and 5·5 ft. in coupes one and two years old respectively.

8. MELANORRHOEA, Wall.

Melanorrhoea usitata, Wall. Varnish tree of Burma. Vern. *Thitsi*, Burm.

A large deciduous tree with a straight clean cylindrical bole and a spreading crown of dark green leaves. Bark thin, dark grey, exfoliating in small angular flakes. Wood dark red, very hard, used for tool-handles, ploughs, building, &c. The chief importance of the tree lies in the varnish obtained from incisions made in the bark and used in Burmese lacquer work. In most parts of Burma the tree attains a height of 50–60 ft. and a girth up to 9 ft. A tree 14 ft. 6 in. in girth has been measured in the Katha district of Upper Burma, but this is exceptional.

Distribution and habitat. This is one of the most characteristic trees of the *indaing* (dry dipterocarp) forests of Burma on laterite soil, where it is associated with *Dipterocarpus tuberculatus*, *Pentacme suavis*, *Shorea obtusa*, *Buchanania latifolia*, and certain other species. It is less common in other types of dry forest, where it prefers gravelly or sandy soil. It ascends to 3,500 ft. and occurs between 15° and 25° N. lat., the most extensive tracts in which it is found being situated in the Southern Shan States, and in the Mu, Katha, Myittha, Upper Chindwin, Ruby Mines, Meiktila, N. Toungoo, and Thayetmyo forest divisions. It has not been reported from Arakan, but extends into Manipur. It is very common in parts of the Southern Shan States, often forming half the growing stock. In its natural habitat the absolute maximum shade temperature varies from 100° to 110° F., the absolute minimum from 40° to 50° F., and the normal rainfall from 35 to 100 in. or more.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The leaves are shed about January–February, and the new leaves appear in March–April. The panicles of small white flowers appear in January–February, when the tree is leafless or nearly so; when covered with white blossom it is a conspicuous sight. The fruits ripen from March to June. The fruit is an irregularly globose drupe (Fig. 101, *a*), the longest diameter 0·5–0·9 in., on a thick stalk 0·3–0·4 in. long, subtended by the five enlarged stellately-spreading stiff membranous petals 2–4 in. long, which are bright red at the time of ripening, turning brown afterwards. The fruits fall parachute-like, revolving rapidly, and may be carried to some little distance from the tree by the strong dry breezes which are prevalent in many localities at the time they ripen. The seed does not retain its vitality long, and germinates soon after falling. Good seed-years are somewhat irregular.

GERMINATION (Fig. 101, *b*, *c*). Hypogeous. The radicle issues, while simultaneously short cotyledonary petioles are developed, between which the plumule emerges. Several roots are developed at an early stage from the base of the young stem.

THE SEEDLING (Fig. 101).

Roots: primary root, usually more than one, moderately long, thick, woody: lateral roots numerous, fibrous, mainly in upper parts of main roots, developing early. *Hypocotyl* absent. *Cotyledons* subterranean: petiole 0·1–0·15 in. long, flattened on inner side: lamina 0·8–0·9 in. by 0·5 in., thick, fleshy, closely cohering, reniform, outer surface rounded, rugulose, inner surface flattened in contact, smooth. *Stem* erect, terete or slightly compressed, green, young parts minutely tomentose, older parts glabrous; internodes 0·4–2 in. long. *Leaves* alternate, exstipulate. Petiole 0·2–0·35 in. long, thick, flattened or channelled above, pubescent or glabrescent. Lamina 1·7–4·6 in. by 1·1–2·5 in., elliptical or obovate, acuminate, base decurrent, entire, glabrous or young leaves sometimes sparsely pubescent beneath, lateral veins 12–16 pairs, conspicuous, running to near the margin. First few leaves usually rudimentary and very small.

The seedling develops somewhat slowly, a height of about 4 or 5 in. being ordinarily attained by the end of the first season; the taproot may attain a length of about 1 ft. or more in that time. The seedlings will not stand cold, and are killed at once by frost.

SILVICULTURAL CHARACTERS. The silvicultural characters of the tree have not been studied in any detail. It is known to be immune from damage by grazing owing to the acrid juice in its leaves. Although a light-demander the tree appears to be able to bear slight shade and to benefit by it in youth.

ARTIFICIAL REPRODUCTION. Experiments have shown that transplanting from the nursery is attended with some risk, and that direct sowing, or transplanting of basket plants, gives better results. The fruits should be collected and sown as soon after ripening as possible, since germination commences not long after they fall.

9. ODINA, Roxb.

Odina Wodier, Roxb. Vern. *Kaimal, jhingan, jigna, mohin,* Hind.; *Jial,* Beng.; *Gugul,* Kan.: *Moi, shembat,* Mar.; *Uthi, odi,* Tam.; *Gumpan,* Tel.; *Nabè,* Burm. (Fig. 98.)

A moderate-sized to large deciduous tree with a spreading crown, stout branchlets, and compound imparipinnate leaves 12–18 in. long. Bark 0·5–0·7 in. thick, grey, smooth in young trees, afterwards exfoliating in thin irregular rounded plates, inside crimson marked with pale pink or white. Heartwood comparatively small, light pink when freshly cut, darkening on exposure, of good quality, used for planking, agricultural and domestic implements, and a variety of other purposes. The bark yields a useful gum which is largely exploited by tapping.

DISTRIBUTION AND HABITAT. A common tree in mixed deciduous forests throughout the greater part of India and Burma and in the Andamans. It occurs throughout the sub-Himalayan tract in sal forests and mixed deciduous forests of the plains and outer hills, ascending the Himalayan valleys and slopes to 4,000 ft. It is common, especially in dry forests, in Bengal, Assam, Chota Nagpur, and throughout the Indian Peninsula. In Burma it is plentiful in both the upper and the lower mixed forests. In its natural habitat the absolute maximum shade temperature varies from 100° to 118° F., the absolute minimum from 30° to 60° F., and the normal rainfall from 30 to 150 in. or more.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The leaves commence falling in November, and from December–January to May–June the tree is leafless. The flower-buds appear about February in stiff terminal racemes at the ends of the leafless branches, and in March–April the trees have a striking appearance when covered with masses of feathery whitish blossoms. The fruits begin to form rapidly, becoming nearly full-sized while the tree is still leafless, and ripening from May to July: the trees at this time are easily recognized from the clusters of small drupes. When ripe the drupe is about 0·5 in. long, oblong, sub-reniform, compressed, red, with a thin fleshy epicarp and a large hard stone. The fruits are eaten by birds and the stones are scattered by their agency. The seeds quickly lose their vitality.

SILVICULTURAL CHARACTERS. The tree is a decided light-demander. It is tender to frost and suffered much in northern India in the severe frost of 1905. In the abnormal drought of 1907 and 1908 in Oudh it proved to be decidedly hardy, and it was only slightly affected in the excessive drought of 1899 and 1900 in the Deccan. It resists fire well. The leaves and young shoots are readily browsed by cattle and goats. It pollards fairly well and produces root-suckers. Its coppicing power varies. Mr. A. E. Osmaston[1] notes that, in experiments in the Gorakhpur forests in 1909–10, of 18 trees felled none produced coppice-shoots: these experiments, however, were carried out after abnormal years of drought, which may have affected the vitality of the stools. Measurements by Mr. C. M. McCrie in the same forests in 1910 showed an average of 3, 2, 1, and 1 shoots per stool in the case of coppice 5, 7, 13, and 15 years old respectively, while measurements by me in the Tikri forest, Gonda, United Provinces, in 1911 showed an average of two shoots per stool in one-year-old coppice.

---

[1] Ind. Forester, xxxvii (1911), p. 429.

ARTIFICIAL REPRODUCTION. The tree grows well from seed or from cuttings. The seed should be sown fresh, as it does not retain its vitality long.

RATE OF GROWTH. Statistics of rate of growth are scanty. Measurements of one tree extending over nineteen years in the Ramnagar division, United Provinces, showed a mean annual girth increment for the period of 0·32 in. Two cross-sections in the silvicultural museum at Dehra Dun showed the following measurements:

1. Age 73 years; girth 3 ft. 9 in.; mean annual girth increment 0·62 in.
2. Age 49 years; girth 3 ft. 10 in.; mean annual girth increment 0·94 in.

The rate of growth of coppice is fast. Coppice measurements made in 1910 by Mr. C. M. McCrie in Gorakhpur gave the following average results for *Odina Wodier* and sal respectively:

Odina Wodier: coppice measurements. Gorakhpur, United Provinces.

	Mean height.		Mean girth.	
Age.	*Odina Wodier.*	Sal.	*Odina Wodier.*	Sal.
years.	ft.	ft.	in.	in.
2	5·8	3·0	2·3	—
4	10·9	7·0	4·1	2·0
6	14·2	10·3	5·8	2·9
8	16·7	13·0	7·3	3·8
10	19·0	15·3	8·6	4·8
12	21·1	17·5	9·8	5·8
14	22·9	19·2	10·8	6·7
16	24·3	20·9	11·5	7·5

My measurements in 1911 in one-year-old coppice coupes in the Tikri forest, Gonda, showed an average height of 5 ft. for *Odina* as against 4 ft. 8 in. for sal.

10. SPONDIAS. Linn.

Spondias mangifera, Willd. Hog plum. Vern. *Amra*, *ambara*, Hind.; *Ambada*, Mar.; *Amate*, Kan.; *Ambalam*, Tam.; *Gwè*, Burm.

A moderate-sized to large deciduous tree with compound imparipinnate fragrant leaves 12–18 in. long. Bark thick, smooth, grey, aromatic, inside pink streaked with lighter pink. Wood soft and of poor quality: the tree yields a tasteless gum and the fruits are pickled. A characteristic Indian forest tree.

DISTRIBUTION AND HABITAT. Throughout the greater part of India and Burma in deciduous, often dry forests. Throughout the sub-Himalayan tract, in Bengal, Assam, Chota Nagpur, the Indian Peninsula generally, Burma, and the Andamans. Although widely distributed it is nowhere abundant or gregarious. In its natural habitat the absolute maximum shade temperature varies from 100° to 118° F., the absolute minimum from 30° to 60° F., and the normal rainfall from 30 to 150 in. or more.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The tree is leafless longer than almost any other forest tree of India. The leaves fall in November–December, sometimes earlier, and the tree remains leafless until April–May or even later. The inflorescences of whitish flowers cover the leafless trees about March–April, and at that time the trees are a conspicuous sight. The fruits form during the rains and commence to ripen in December, continuing to ripen and fall until February or March. The trees at this time are easily recognized by the pendulous clusters of drupes. The drupes are 1·5–2 in. long, ellipsoidal, yellow when ripe, smooth, fleshy, with a hard somewhat fibrous stone furrowed and pitted on the surface: the stone (Fig. 102, *a*) is 2- to 5-celled, sometimes 6-celled, with 1–3 fertile seeds. The fruits are greedily eaten by deer, pigs, monkeys, squirrels, and other animals, and the large bare stones with the flesh removed may be found scattered about the forest from the time the fruit ripens onwards. Small heaps of these stones are continually met with in places where deer have lain ruminating and bringing them up. The seed of stones collected from these heaps has been found to germinate well. About 70–130 stones weigh 1 lb. Tests carried out at Dehra Dun showed that a proportion of the seeds retained their vitality for one year, namely 60 seeds per 100 stones as against 130 seeds in the case of fresh stones; another sample kept for a similar period failed to germinate.

GERMINATION (Fig. 102, *b–d*). Epigeous. The radicle and plumule emerge almost simultaneously through a hole near one end of the fruit-stone, the testa remaining within the stone. The hypocotyl arches during germination, soon straightening: there is a distinct kink or elbow at its base owing to the efforts of the seedling to emerge from the stone. From one to three seedlings may emerge from the same stone, so that the seedlings are sometimes found in groups of two or three.

THE SEEDLING (Fig. 102).

Roots: primary root moderately long, at first thin, soon becoming thick and somewhat fleshy, terete, tapering, whitish, tomentose: lateral roots numerous, long, fibrous, tomentose, distributed down main root. *Hypocotyl* distinct from root, 1·5–3 in. long, terete, tapering slightly upwards, with a distinct bend at the base, fleshy, green, glabrous, arched during germination. *Cotyledons* sessile, 1·2–1·5 in. by 0·3 in., somewhat fleshy, linear lanceolate, acute, entire, green, glabrous, obscurely parallel veined on lower surface. *Stem* erect, terete or slightly grooved, glabrous; internodes 0·4–1·2 in. long. *Leaves* compound, exstipulate, first pair opposite or sub-opposite, subsequent leaves alternate. First pair 3-foliate, common petiole 0·4–1·2 in. long. Subsequent leaves imparipinnate, usually 5- or 7-foliate in first season; rachis 0·8–4 in. in first season, often reddish; leaflets shortly petiolate, 1–3·5 in. by 0·5–1·3 in., elliptical oblong, acuminate, serrate or entire, glabrous.

During the first year or two the seedlings show moderately fast development under natural conditions, that is, where no weeding and watering is done; subsequently they develop more rapidly. They are capable of establishing themselves in grass and moderate weed-growth, but weeding greatly stimulates their growth. The maximum height of seedlings raised at Dehra Dun, and not watered, was as follows:

(1) End of first season 7 in., both weeded and unweeded; (2) end of

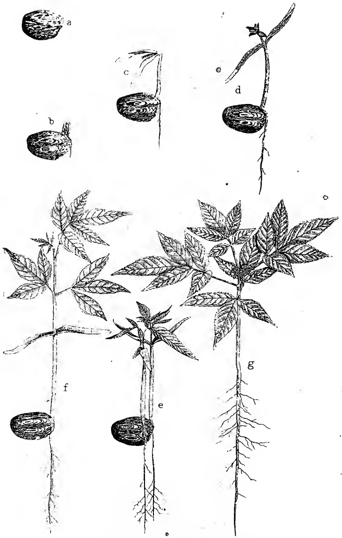

Fig. 102. *Spondias mangifera*. Seedling × ⅓.
a, stone of drupe; *b–d*, germination stages; *e–g*, development of seedling to end of first season.

second season 21 in. unweeded, 34 in. weeded ; (3) end of third season 5 ft. 10 in. **unweeded,** 9 ft. 2 in. weeded ; (4) end of fourth season 6 ft. unweeded, 12 ft. 9 in. (girth 7 in.) weeded. Where two or three seedlings emerge from one fruit one eventually takes the lead, suppressing the others. In northern India the season's growth ceases about October–November, and new growth commences in March–April ; the seedlings are leafless from December to March–April. The seedlings are somewhat frost-tender, but have good power of recovery from the base : they are also sensitive to drought in the first year or two. Rats are occasionally destructive to them, gnawing through the taproot and killing them.

SILVICULTURAL CHARACTERS. The tree is a decided light-demander. It is sensitive to frost, and suffered much in northern India in the abnormal frost of 1905. It coppices, but is not known to produce root-suckers.

NATURAL REPRODUCTION. The fruit-stones, from which the fleshy covering has usually been stripped by animals, lie on the ground from the time the fruits fall in the cold season until the rains, when germination takes place. If the stones are lying on the surface of the ground at the time of germination the radicle is very apt to dry up or to become eaten by birds or insects before it reaches the soil. Many stones, however, become covered with earth and débris during the months in which they lie on the ground, and particularly during the early showers preceding the monsoon rains : this promotes successful germination, which is still further ensured by the fact that many fruits do not germinate until the second rains, and thus have every opportunity of becoming covered with earth during the long period in which they lie on the ground. For the establishment of natural reproduction, abundance of light is necessary.

ARTIFICIAL REPRODUCTION. The tree can be propagated from cuttings or from seed. In the latter case direct sowings give better results than transplanting, provided the fruit-stones are covered with earth. Nursery-raised seedlings should be transplanted when about 3 in. high during the first rains, but considerable care is necessary to retain earth round the roots and to avoid exposing them. More success is attained by transplanting seedlings raised in baskets.

RATE OF GROWTH. The rate of growth is known to be fairly rapid, though detailed measurements are not available. A cross-section 2 ft. 6½ in. in girth in the silvicultural museum at Debra Dun showed 22 rings, representing a mean annual girth increment of 1·4 in.

ORDER XXII. MORINGACEAE

MORINGA, Lam.

Moringa pterygosperma, Gaertn. Syn. *M. oleifera*, Lam. Horse-radish tree. Vern. *Sanjna*, *sohanjna*, Hind. : *Shevgi*, Mar. ; *Nuggi*, Kan. ; *Moringa*. Tam. ; *Danthalun*, Burm.

A small to moderate-sized tree with thick soft grey corky deeply fissured bark and elegant feathery foliage of large tripinnate leaves. The wood is soft and useless, but the fruit is used as a vegetable, the branches are much lopped for fodder, especially for camels, and the inner bark, and more particularly the roots, are used as a substitute for horse-radish, which they resemble in flavour. The seeds yield an oil of fine quality similar to the *ben oil* of watchmakers, which is the produce of *M. aptera*, Gaertn., an African tree. The cultivation of *M. pterygosperma* for the sake of this oil has been recommended. The tree is indigenous in the sub-Himalayan tract from the Chenab to the Sarda, and in Oudh, growing plentifully on recent alluvial land in or near the sandy or shingly beds of rivers and streams. In its natural habitat the absolute maximum shade temperature varies from 110° to 118° F., the absolute minimum from 30° to 37° F., and the normal rainfall from 30 to 85 in. It is cultivated in many parts of India. The leaves turn yellow and fall in December–January, the leaflets falling separately, and the new foliage appears about February–March. The fragrant handsome white flowers, in numerous panicles near the ends of the branches, appear from January to March, and the fruits ripen from April to June. The fruit is a pendulous ribbed pod-like capsule, 9–20 in. long, with numerous three-cornered seeds winged at the angles. The trees can be raised either from seed or from large cuttings, the latter striking well if watered sufficiently. It coppices and pollards vigorously.

ORDER XXIII. LEGUMINOSAE

Includes sub-orders I. PAPILIONACEAE, II. CAESALPINIEAE, III. MIMOSEAE.

This order is, numerically speaking, by far the most important one in Indian silviculture, containing as it does a much larger number of important trees than any other order. In addition to trees, it includes numerous shrubs of the undergrowth or of open places, some useful for clothing barren ground, such as *Cassia auriculata*, *Acacia* spp., *Dichrostachys cinerea*, &c., or bare hill-sides, for example *Desmodium*, *Indigofera*, &c., others of a scrambling or scandent nature, impeding forest growth. Many of the large climbers, which require to be cut periodically in the interests of tree growth, belong to this order: some of the best known of these are *Millettia auriculata*, *M. racemosa*, and other species of *Millettia*, *Spatholobus Roxburghii*, *Butea superba*, *Mucuna macrocarpa*, *Derris scandens*, *Bauhinia Vahlii* and several other species of *Bauhinia*, *Entada scandens*, *Acacia pennata*, and other scandent acacias.

Many species are cultivated for the sake of their ornamental flowers, for example *Amherstia nobilis*, one of the most beautiful flowering trees in the world, *Poinciana regia*, *P. elata*, *Saraca indica*, *Cassia Fistula*, *C. renigera*, *C. nodosa*, and many others. Many yield economic products of value, such as tans furnished by *Caesalpinia digyna* and *C. Coriaria* (pods), *Cassia auriculata* (bark), *Acacia arabica* (bark and pods), *A. leucophloea* (bark), and *A. Catechu* (cutch extract from the heartwood), gums yielded by *Acacia Senegal*, *A. arabica*, *A. modesta*, *Bauhinia retusa*, *Pterocarpus Marsupium* (gum-kino), and *Butea frondosa*, bast-fibres, drugs, and other products.

Among such a large number of genera and species the silvicultural characters vary considerably, though some of these characters are common to a good many. Perhaps one of the most marked characteristics is the effect of soil-aeration on the development of young plants. In the descriptions of the seedlings of the various species many examples will be found of the marked growth obtained on ground kept well weeded and loosened, as compared with the growth on ground not weeded and loosened: this is true of plants in general, but it is perhaps nowhere so well marked as in the case of the Leguminosae, a fact which may possibly be due, in part at least, to the effect of aeration on the nitrogen-fixing nodules found on the roots of many of the species.

The pods and their dehiscence, and the spread and germination of the seed, are of considerable interest. Among pods which are indehiscent even during germination are those of *Dalbergia* spp., in which the young plant breaks through the pod valves. The pods of *Cassia Fistula*, as far as can be ascertained, require the aid of animals to liberate the seeds. In the case of *Acacia arabica* pods, although the seed is usually scattered by animal agency the pods may otherwise lie on the ground until the valves rot, the seed escaping in this way. In *Butea frondosa*, *Pongamia glabra*, *Ougeinia dalbergioides*, *Pterocarpus* spp., and *Hardwickia binata* dehiscence, which may be only partial, takes place during germination; in the first two species germination is hypogeous, the cotyledons remaining within the pod or sometimes escaping from it, while in the remainder germination is epigeous and the pod valves are always thrown off before germination is completed. Of pods which dehisce tardily, and as a rule after falling, may be mentioned those of *Acacia Farnesiana* and of several species of *Albizzia*; the pods of the latter are flat and thin, and can be blown some distance by the wind, the seed being thus disseminated. Pods which dehisce on the tree before or about the time of falling may be of two types: (1) those in which the seeds cling by means of a tenacious funicle to the pod valves, which in many cases are light and are easily carried by wind, the seeds being thus scattered to some distance from the tree, for example *Robinia Pseudacacia*, *Acacia Catechu*, and *A. Melanoxylon*; (2) those from which the seed falls out during or not long after dehiscence, and is in some cases ejected and scattered by the sudden opening of a pod with woody elastic valves, for example *Xylia* and some species of *Bauhinia*.

Among light or flat pods, in some cases winged, which are adapted for disseminating the seed by wind, may be mentioned those of *Pterocarpus* spp. (winged), *Hardwickia binata* (winged), *Butea frondosa* (winged), some species of *Dalbergia*, *Ougeinia dalbergioides*, *Robinia Pseudacacia*, and *Acacia Catechu*.

Some pods form rapidly and fall not long after the flowering, for example those of *Butea frondosa*, *Ougeinia dalbergioides*, *Erythrina* spp., *Bauhinia variegata*, *B. purpurea*, *B. retusa*, and *B. malabarica*. Others form rapidly and soon reach full size, but do not ripen for some time, and in some cases may hang long on the tree, for example those of *Dalbergia Sissoo*, *Pterocarpus* spp., *Hardwickia binata*, *Robinia Pseudacacia*, and *Albizzia* spp. A certain proportion of the pods are blown down during strong winds, dissemination of the seed being thus ensured, while in many cases the pods are scattered at various times and do not fall at once, a fact which will often ensure at least a certain proportion of the seed-crop falling under conditions favourable for reproduction.

The seeds of many leguminous species retain their vitality for some time, some hard seeds of acacias being known to remain fertile for several years. Many germinate very readily with sufficient moisture, but among these germination is frequently delayed until the second or even the third year, particularly in the case of seed lying in the shade where the temperature is insufficient to stimulate activity, this is seen in ***Cassia Fistula, Bauhinia*** *malabarica, B. racemosa, Prosopis spicigera,* ***Acacia arabica, Albizzia Lebbek,*** *A. stipulata,* and *A. procera.* Some seeds germinate tardily owing to the existence of an impervious layer in the testa, and various measures have been suggested in order to hasten germination, for example burying the seeds for some time in moist manure, or soaking them for a short time in alcohol and then placing them for a time in water, the alcohol penetrating the impervious layer and the water subsequently penetrating it owing to the readiness with which it mixes with the alcohol, or cutting through the impervious layer with the smallest possible cut of a knife or file (see under ***Caesalpinia digyna***): in the case of seeds of *Cassia Fistula* boiling them for about five minutes before sowing is reported to have given very good results.[1]

In the descriptions of the various species dealt with below it will be seen that in the case of most species covering the seed with soil has a marked influence on successful germination. Seeds which germinate on the surface of the ground are liable to rot in damp localities, to dry up in dry weather, or to have their radicles destroyed by birds or insects, whereas seeds which have become covered with soil escape destruction from these causes. This explains to some extent the success with which reproduction of many species establishes itself on loose bare ground, where much of the seed becomes covered with earth or sand during the early showers preceding the monsoon.

As regards the artificial propagation of leguminous trees, a marked feature is the superiority of direct sowing over transplanting, and the superiority of line sowings over other forms of sowing because of the facility with which weeding and loosening of the soil can be carried out. Most species transplant with difficulty for forest purposes. Some can be transplanted with success after pruning down the stem and cutting off a portion of the taproot, whereas intact plants are very difficult to transplant; this is notably the case with *Dalbergia Sissoo.* Others cannot stand any pruning of the taproot, for example *Acacia Catechu* and *A. arabica*; transplanting of such species is particularly difficult. *Butea frondosa, Albizzia Lebbek, A. stipulata,* and *A. procera* can be transplanted either intact or after pruning the stem and root, though the latter method is preferable. Some species can be propagated by cuttings, for example *Erythrina, Robinia, Pongamia glabra, Adenanthera pavonina,* and others. *Amherstia nobilis* is usually propagated by layers.

Some leguminous trees produce root-suckers rarely or not at all, whereas others produce them with great freedom; among the latter are ***Robinia Pseudacacia, Butea frondosa, Ougeinia dalbergioides, Dalbergia Sissoo, D. latifolia, Dichrostachys cinerea, Acacia dealbata, A. decurrens, Albizzia lucida.*** *A. mollis, A. odoratissima,* and many others.

SUB-ORDER I. PAPILIONACEAE

Genera 1. OUGEINIA, Benth.; 2. **BUTEA**, Roxb.; 3. **ERYTHRINA**, Linn.; 4. PTEROCARPUS, Linn.; 5. **DALBERGIA**, Linn. f.; 6. **PONGAMIA**, Vent.; 7. ROBINIA, Linn.

---

[1] Forest Report, Bihar and Orissa, 1917-18.

1. OUGEINIA, Benth.

Ougeinia dalbergioides, Benth. Syn. *Dalbergia ougeinensis*, Roxb. Vern. *Sandan, chanjan, tinsa, tinas, pánan*, Hind. ; *Tiwas*, Mar.

A small to moderate-sized deciduous tree, often with a crooked stem. Leaves pinnately trifoliate. Crown full and rounded in well-developed trees. Bark up to 0·5 in. thick, ashy-grey or light brown with regular longitudinal and horizontal cracks, exuding a red gum when cut. The following are the average results of a number of measurements of bark thickness made in the Tirsal forest, Debra Dun :

Girth of tree	0–6 in.	6 in.–1 ft.	1–2 ft.	2–3 ft.
Bark thickness	0·15 in.	0·27 in.	0·37 in.	0·4 in.

Wood, hard, close grained, strong and durable, much in request for agricultural implements, wheel-work, house-posts, and other purposes. In exceptional cases the tree attains a girth of 7 ft. and a height of 60 ft., but ordinarily it does not grow in any quantity to more than 4½ ft. in girth and 30–40 ft. in height.

Distribution and habitat. The sub-Himalayan tract and outer Himalayan valleys and slopes up to 5,000 ft., from the Punjab to Bhutan. Chota Nagpur, Central India, Orissa and the Circars, the Central Provinces, and Bombay. The tree occurs in parts of the Marwar state of Rajputana, but is of small size and is not abundant.

In the Peninsula it is found in mixed deciduous forest, where it is sometimes abundant and almost gregarious. In parts of the Central Provinces it reaches very fair dimensions with a straight clean bole. It is by no means exacting as to soil, and is found on a variety of geological formations, including shale, gneiss, trap, laterite, sandstone, quartzite, &c., and on a variety of soils, including black cotton soil, red clay, and gravel or boulder deposits, and will thrive on very poor ground, where, however, it does not attain large dimensions: on alluvial loam it attains a comparatively large size. It is very characteristic of landslips, banks, the sides of ravines, and other exposed places. In the Peninsula some of its more typical companions are *Terminalia tomentosa*, *T. belerica*, *Anogeissus latifolia*, *Lagerstroemia parviflora*, *Buchanania latifolia*, *Butea frondosa*, *Phyllanthus Emblica*, *Pterocarpus Marsupium*, *Dalbergia latifolia*, *Xylia xylocarpa*, and teak. In the sub-Himalayan tract and outer hills it is often found associated with the first seven of the foregoing species and also with sal, *Bauhinia* spp., and at higher elevations with *Pinus longifolia*. It is very common both in mixed deciduous forest and in sal forest : it ascends higher than most plains species, but at the higher elevations it is of small size. In its natural habitat the absolute maximum shade temperature varies from 100° to 115° F., the absolute minimum from 30° (sometimes less) to 45° F., and the normal rainfall from 35 (rarely less) to 70 in.

Leaf-shedding, flowering, and fruiting. The old leaves are shed in January–February, turning yellow before falling, and the new leaves appear in March–April. The lilac or whitish flowers, in fascicled racemes, appear in February–March, and in the flowering season the trees are a conspicuous and beautiful sight. The pods (Fig. 103, *a*) form quickly, and ripen in May–June : they are 2–4 in. by 0·3 in., flat, jointed, light brown, with 2–5 seeds. The seeds

(Fig. 103, *b*) are 0·4–0·5 in. by 0·2–0·25 in., flat, reniform, light brown, with a thin testa and an even thinner papery tegmen. The pods fall chiefly in June–July: they are dehiscent during germination, but hardly before. Existing seed-year records show that the tree does not seed abundantly every year. Root-suckers of comparatively small size produce flowers and fruits.

Germination (Fig. 103, *c–m*). Epigeous. If the seeds are extracted from the pods and sown separately, germination commences with the emergence of the radicle, the hypocotyl arching and drawing the cotyledons out of the ground. The testa is either left in the ground or carried up; the inner papery tegmen is usually carried up, dropping on the expansion of the cotyledons. Under natural conditions the seeds ordinarily germinate within the pods or pod sections, which dehisce slightly and enable the radicle to push its way through between the valves. The shell of the pod may either be left in the ground, or, as is more frequent, may be carried up and dropped on the expansion of the cotyledons.

The seedling (Fig. 103).

Roots: primary root long, terete, tapering, wiry: lateral roots moderate in number, fibrous: nodules present. *Hypocotyl* distinct from root, 1·2–2 in. long, terete, tapering upwards, white turning green, tomentose, arched during germination. *Cotyledons*: petiole 0·05 in. or less: lamina 0·5–0·8 in. by 0·3–0·4 in., foliaceous, slightly plano-convex, somewhat fleshy, unequally ovate or reniform with an angular projection on the basal half of the incurved side, apex rounded, base obtuse, entire, green, glabrous. *Stem* erect, terete, zigzag at the nodes, green, young parts reddish, pubescent; internodes 0·3–1 in. long. *Leaves*, first pair simple, opposite, subsequent leaves trifoliate, or sometimes one simple, alternate, at first small, succeeding leaves becoming larger. Stipules about 0·1 in. long, linear. Simple leaves with petiole 0·3–0·6 in. long, slender, channelled above, pubescent; lamina 0·7–1·4 in. by 0·5–0·8 in., cordate or broadly ovate, acute, entire, glabrous above, pubescent on veins of lower surface, lateral veins 4–6 pairs. Trifoliate leaves with common petiole 0·7–3 in. long, channelled above, pubescent; petiolules up to 0·1 in. long; stipels less than 0·1 in., linear; leaflets, terminal 1·2–3·5 in. by 0·8–2·4 in., lateral opposite, 0·6–2·5 in. by 0·5–1·5 in., broadly ovate, acute, entire, base obtuse, glabrous above, pubescent on veins beneath. Young leaves deep coppery red. older leaves green, paler beneath.

The seedling is of comparatively slow growth, the maximum height attained in beds which are weeded and watered being about 2 ft. in the first season, while under natural conditions the height attained is ordinarily about 3 to 6 in. in the same time. In their early stages the seedlings are tender to drought, and die off in quantity if exposed to a hot sun: they are also frost-tender. The development of the seedlings is better and mortality is less in slight shade, but in very heavy shade the seedlings do not survive. Weeding stimulates development; a slight growth of weeds and grass does little or no harm, but heavy weeds kill off the seedlings. The taproot varies considerably: as a general rule a long taproot is formed at an early stage, and may reach a length of 2 ft. within two months. The seedlings lose their leaves in January–February, and the new leaves appear in February–March. The young leaves are coppery brown in colour.

Silvicultural characters. The tree stands a fair amount of shade when young, and requires a certain amount of protection from the sun in its early stages. Once it is established, however, it requires full overhead light for its best development. Although in early youth it is tender both to drought and to frost, it is afterwards hardy. In the abnormal drought of 1907 and 1908 in the forests of Oudh it proved to be decidedly hardy, as it did also in the severe frost of 1905 in northern India. It is much subject to browsing by cattle and deer. It coppices well and produces root-suckers in great abundance, particularly along steep banks and on hill-sides, where suckers may be seen issuing even from the joints on the sides of cliffs; on this account it is a useful tree for clothing unstable hill-sides. It suffers considerably from fire, and responds readily to fire-protection. As already mentioned, it is not exacting as regards soil, and will grow on decidedly poor ground. The root-system of the tree is characteristic: in addition to a taproot which is often twisted and branched, with numerous lateral rootlets for purposes of nutrition, there are superficial roots, often of great length and considerable thickness, spreading along or near the surface of the ground; roots of the former type have no buds, but those of the latter type, which are for propagation purposes, have numerous buds from which root-suckers are produced.

Natural reproduction. Under natural conditions the flat light pods are carried by wind to some distance from the tree immediately before and at the commencement of the monsoon, and germination takes place early in the rains. The seed germinates and the seedlings establish themselves best on bare loose ground, and for this reason profuse natural seedling reproduction often appears along the sides of roads, on ground exposed by landslips, and on cultivated ground even while the fields are still under cultivation. In the outer Himalaya and also in the Peninsula the sites of former fields are sometimes marked by dense crops of *Ougeinia*, which is one of the first species to make its appearance. Observations in experimental plots have shown (1) that on hard bare ground, where the seed germinates on the surface, great mortality occurs through drought, the radicles drying up before they can penetrate the soil: this is particularly the case in open places exposed to the sun; (2) that seed falling among weeds and grass, if these are at all dense, tends to rot before or during germination, and natural reproduction thus fails; in sunny places where the growth of weeds or grass is sufficiently scanty, these may be beneficial in affording protection from the sun; (3) that slight or moderate shade favours the germination and development of the seedlings by protecting them from the sun, but dense shade kills them off. As already mentioned, root-suckers form a very important means of reproduction, particularly on hill-sides and other places where the roots are exposed. Much of the reproduction found on deserted fields after temporary cultivation consists of root-suckers, probably from original seedlings which appear when the fields are under cultivation and survive the weeding and cutting back, which is often not intense.

In the forest pure natural crops of great density are often met with, sometimes under the light shade of other trees and sometimes in gaps in the forest crop. In the Tirsal forest, Dehra Dun, a dense mass of reproduction up to 4 ft. high in an area overrun by fire two years previously, and thus consisting of shoots two years old, contained 415 stems on an area of 318 square ft., or 56,800 per acre. Three years later the number of stems had been reduced in the struggle for existence to 230, or about 31,500 per acre. Another plot in the same forest, estimated to be fifteen years old, contained about 11,600 stems per acre; the average height and girth were 16 ft. and 5·4 in. respectively.

Artificial reproduction. Various experiments have been carried out at Dehra Dun in the artificial propagation of this tree. It was found that reproduction by stem cuttings gave indifferent results, while planting root cuttings was quite successful, a considerable proportion sending up suckers; the thicker root cuttings were found to produce more vigorous shoots than the thinner ones. As regards reproduction by seed, the best results were obtained by line sowings with regular weeding, 1 lb. of pods being required for 300 ft. of line. These sowings, carried out with the aid of field crops, proved very successful. The whole ground was ploughed up, the pods being sown shortly before the break of the monsoon in lines 10 ft. apart; the lines were kept clear of field crops to a width of 2 ft., the crops being sown in the spaces, 8 ft. wide, between the lines. The crop employed was the lesser millet or *mandwa* (*Eleusine coracana*), which was found to give such dense cover as to suppress the seedlings if sown continuously over the area. The crops may be cultivated for one, two, or even three seasons, and while the area is under cultivation the lines of seedlings are weeded by the cultivator. Ordinary line sowings without field crops on lines well ploughed to a width of 1½ ft. also proved successful, provided regular weeding was carried out.

Transplanting from the nursery has also proved moderately successful, provided young plants are used before they have developed long taproots. The pods should be sown in the nursery in May or early June in drills 9 in. apart and lightly covered with earth, the beds being regularly watered: the seedlings should be transplanted early in the rains, while still only a few inches high. Direct sowing, however, is so much more successful than transplanting that the latter is not to be recommended on a large scale.

Rate of growth. It is impossible to ascertain the rate of growth from annual rings as these are not distinct. Sample plot measurements indicate a comparatively slow rate of growth. In the United Provinces measurements in nine sample plots in four forest divisions gave the following results:

Ougeinia dalbergioides: measurements in high forest sample plots, United Provinces.

No.	Forest division.	Number of years under observation.	Girth classes.	Mean annual girth increment for the period.
		years.	ft.	in.
1	Saharanpur	12	0–1	0·41
			1–2	0·22
			2–3	0·20
2	Dehra Dun	10	1–2	0·54
3	Lansdowne	17	1½–3	0·13
4	,,	15	1½–3	0·43
5	,,	13	1½–4½	0·43
6	,,	7	1½–3	0·39
7	,,	5	1½–4½	0·27
8	Ramnagar	19	1½–3	0·29
9	Haldwani	11	1½–4½	0·52

As regards coppice, measurements made in 1910 by Mr. C. M. McCrie in the Gorakhpur district, United Provinces, gave the following results for ***Ougeinia*** as compared with sal :

Ougeinia dalbergioides : rate of growth of coppice, Gorakhpur.

	Mean height.		Mean girth.	
Age.	*Ougeinia.*	Sal.	*Ougeinia.*	Sal.
years.	ft.	ft.	in.	in.
2	3·0	3·0	—	—
4	5·2	7·0	1·6	2·0
6	7·0	10·3	2·2	2·9
8	8·3	13·0	2·7	3·8
10	9·5	15·3	3·2	4·8
12	10·3	17·5	3·6	5·8
14	11·2	19·2	3·8	6·7
16	11·8	20·9	4·0	7·5

Measurements made in 1916 in the Saitba coppice coupes, Kolhan, Bihar and Orissa, on poor hilly ground, gave the following results :

Ougeinia dalbergioides : rate of growth of coppice, Saitba.

Age.	Mean height.	Mean girth.	Age.	Mean height.	Mean girth.
years.	ft.	in.	years.	ft.	in.
2	3·5	1·5	10	14·0	6·2
4	7·0	3·2	12	15·5	6·9
6	10·0	4·3	14	17·0	7·5
8	12·0	5·3			

2. BUTEA, Roxb.

Butea frondosa, Roxb. Vern. *Dhák, palás, kakria, chalcha*, Hind. ; *Muttuga*, Kan. ; *Parás, palás*, Mar. ; *Parasu*, Tam. ; *Modugu*, Tel. ; *Pauk*, Burm.

A moderate-sized deciduous tree, with a rather crooked irregular trunk and branches and a somewhat open crown, with large trifoliate leaves. Bark moderately thick, fibrous, grey or light brown, exuding a red juice when cut. The tree sometimes reaches a fairly large girth ; Mr. A. E. Wild records one of 12 ft. 9 in. in Palamau. The wood is not of much value as timber, but is fairly durable in contact with water, and is used for well-curbs, water-scoops, &c. The chief use of the tree is for the propagation of lac, in which respect it ranks second only to *Schleichera trijuga* among the trees of India. The leaves are lopped for buffalo fodder, and are used as plates, the bark, particularly that of the roots, gives a coarse fibre, and the red juice which exudes from cuts in the bark hardens into a red astringent gum known as ' Bengal kino ', used in medicine. Silviculturally the tree is of importance as being one of the commonest trees of the plains of India, and as being capable of thriving on saline soils and badly drained ground where most species will not grow.

DISTRIBUTION AND HABITAT. Common throughout the greater part of India and Burma, ascending the outer Himalaya to about 3,000 ft. or occasionally higher, the Khandesh Akrani to 3,700 ft. (Talbot), and the hills of southern India to 4,000 ft. : rare or absent in the most arid regions. The tree is very typical of open grass-lands, where it is frequently gregarious, as in the *tarai* country of northern India. It grows in water-logged situations, on black cotton soil, and even on saline soil. It is a characteristic tree on the plains of India, often forming pure patches in grazing grounds and other open places, escaping extermination owing to its immunity from grazing, and its power of reproduction from seed and root-suckers and of recovery from the effects of constant lopping. It is common in certain types of mixed deciduous forest of an open character; in parts of the Central Provinces, for example, a common type is that in which it occurs mixed with *Terminalia tomentosa*, *Diospyros Melanoxylon*, *Acacia Catechu*, and *A. leucophloea*. In Burma it is most characteristic of open lower mixed or savannah forests, associated with *Stephegyne parvifolia*, *Dalbergia cultrata*, *D. purpurea*, *Careya arborea*, *Anogeissus acuminata*, *Terminalia pyrifolia*, and other trees growing in extensive tracts of savannah grass, where it also frequently occurs pure or nearly so. Bourdillon says that in Travancore it is confined to the drier parts of the country, where it is found growing in grass-land up to 4,000 ft.

In the natural habitat of the tree the absolute maximum shade temperature varies from 100° to 120° F., the absolute minimum from 25° to 60° F., and the normal rainfall from 25 to 180 in. or more.

Leaf-shedding, flowering, and fruiting. The leaves begin to fall at the end of November or during December, and by the end of January some trees are leafless or nearly so; others may retain their leaves, particularly on the lower branches, during the flowering season, up to the end of March. The new leaves appear in April or early May, and are of a delicate fresh green colour. The blackish flower-buds appear on the bare branches in January, and from the end of that month and through February and March the trees herald the hot weather by bursting forth in a blaze of scarlet blossom, presenting a gorgeous sight which if once seen can never be forgotten: the tree is on this account appropriately termed the 'flame of the forest'. At the time of flowering the trees are either entirely leafless or the leaves may linger on the lower branches, the flowers chiefly covering the upper part of the tree. Flowering continues, according to locality, until the end of March or the end of April. Seasonal conditions influence the time of flowering to a considerable extent; it takes place earlier than usual in dry seasons.

The fruit forms very rapidly, the scarlet flowers quickly giving place to pale green flat pods, which often attain a length of 2 to 3 in. before all the flowers have fallen. In April the leafless trees are often covered with the flat green pods, and appear as if in full foliage. The pods (Fig. 104, *a*) ripen in May–June, and fall soon after ripening, being blown to some distance from the trees by the stiff breezes which are common at that time. The pods when ripe are greyish yellow, 4–8 in. by 1·4–1·8 in., ligulate, pendulous, firm, silky tomentose, with one seed near the apex; the pod is dehiscent at the apex during germination. The seed (Fig. 104, *b*) is flat, reniform, 1·3–1·5 in. by 0·9–1 in., with a thin papery reddish brown testa. Tests carried out at Dehra Dun have shown that the seed loses its vitality within a year, but fresh seed has a very high germinative power.

Germination (Fig. 104, *c–f*). Hypogeous. The seed does not escape from the pod: the latter dehisces at the apex, and the emergence of the radicle and plumule is effected by the development of short cotyledonary petioles. The cotyledons remain attached to the seedling for a considerable time after germination.

The seedling (Fig. 104).

Roots: primary root long, very thick, fleshy, terete, tapering, pale yellow at first, becoming brown, pubescent when young: lateral roots moderate in number, fibrous, pubescent when young, distributed down main root. *Hypocotyl* very short and scarcely distinguishable. *Cotyledons* subterranean: petiole 0·5–0·7 in. long, fleshy, flattened, glabrous, curving to side of stem: lamina 1·1–1·6 in. by 0·9–1·1 in., flat, fleshy, reniform, yellow. *Stem* erect, terete, green, tomentose; first internode, between cotyledons and first pair of opposite leaves, 3–5 in. long, subsequent internodes much shorter. *Leaves*, first pair simple, opposite, subsequent leaves trifoliate, alternate. Stipules 0·1–0·15 in. long, sub-falcate or triangular acuminate, tomentose. Stipels of compound leaves 0·1–0·15 in., triangular or linear acuminate, tomentose. Simple leaves with petiole 0·15 in. long, thick, terete, tomentose; lamina 2·5–5 in. by 2·5–4·5 in., broadly or obliquely ovate or rhomboidal, obtuse or acute, mucronate, entire, pubescent, venation arched reticulate, lateral veins 6–9 pairs. Trifoliate leaves with common petiole 2–5 in. long, green, pubescent. Leaflets with thickened petiolules 0·15–0·2 in. long, tomentose. Terminal leaflet 2·5–5 in. by 2–4 in., rhomboidal ovate or obovate, acute or obtuse, mucronate; lateral leaflets opposite, 1·5–4·5 in. by 1–3 in., unequally ovate, acute or obtuse, mucronate; all leaflets entire, glabrous or slightly pubescent above, pubescent beneath, lateral veins 5–9 pairs.

The development of the seedling varies greatly according to the conditions under which it grows. It is capable in the first season of struggling against heavy weed-growth, but continued suppression of this kind kills it within the next year or two. On stiff ground also the development is slow, although the seedling is capable of surviving. Weeding and irrigation greatly stimulate the growth, the former being even more important than the latter. Experiments at Dehra Dun showed that under ordinary natural conditions a height of about 4–6 in. is attained by the end of the first season; on stiff ground or among comparatively heavy weeds the subsequent growth may amount to only one or two inches a year. The effects of weeding and irrigation are illustrated by the following figures of growth in experimental plots at Dehra Dun:

Maximum height of *Butea frondosa* seedlings at end of first three seasons. Dehra Dun.

	Irrigated.				Not irrigated.			
End of season.	Weeded.		Not weeded.		Weeded.		Not weeded.	
	ft.	in.	ft.	in.	ft.	in.	ft.	in.
1st	2	2	1	2	1	8	0	5
2nd	8	0	2	6	4	6	0	10
3rd	12	9	3	0	8	10	1	7
							(plants weakly)	

The seedling develops a very long taproot at an early stage, a length of as much as 2 ft. being sometimes attained in three months, and 4½ ft. by the end of the first season. The upper part of the taproot is thick and fleshy for several inches from the top, attaining a diameter of 1–1·7 in. Except under favourable conditions the seedlings die back for some inches from the top or down to ground-level either in the cold season (if due to frost) or in the hot season (if due to drought), new shoots being sent up subsequently. This dying back may continue for two or three successive years or more, until the plants become sufficiently established to send up permanent shoots. In the case of vigorous plants in irrigated or weeded sowings this dying back does not take place, but it occurs very commonly in the case of transplants, among heavy weeds, in frosty localities, in dry climates or situations, and on stiff soils.

The thick fleshy taproots are readily devoured by rats, which burrow underground and attack them, or by pigs and porcupines, which grub them up. The roots, however, have wonderful power of recovery, and unless almost entirely eaten away they will send up new shoots from the portions left untouched. Line sowings at Dehra Dun were thinned out by driving a long knife down through the taproots and severing them as low down as possible, the plants being then pulled up, but all the pieces of root remaining in the ground subsequently produced vigorous shoots. This power of recovery is noticeable in the case of certain other species with thick fleshy roots, for example *Bombax malabaricum* and *Hymenodictyon excelsum*. It renders the seedlings particularly hardy, for although they are liable to be killed back by frost and drought they almost invariably produce new vigorous shoots from the base. The seedlings are avoided by cattle and goats.

The leaves of seedlings drop about January to March: new growth starts in March–April, or sometimes not till May.

SILVICULTURAL CHARACTERS. Although it grows typically in open places, the tree is capable of standing a fair amount of shade. In its natural habitat it is frost-hardy; in severe frosts, as in that of 1905 in northern India, the leaves shrivel up and fall, but as a rule little or no permanent damage is done. The tree is very drought-resistant, as was proved in the abnormal drought of 1907–8 in the forests of Oudh, and in that of 1899–1900 in the Indian Peninsula, when young plants of this species were almost the only ones which escaped in the worst affected areas. The leaves are not browsed by cattle or goats, and for this reason the tree is favoured in heavily grazed areas, where it may form pure masses, particularly on black cotton soil. The tree coppices and pollards well, and produces root-suckers freely: the results of pollarding experiments for lac cultivation are given below.

NATURAL REPRODUCTION. The seeds germinate early in the rainy season not long after the fall of the pods; at this time numerous young seedlings with pods still attached may be found in the neighbourhood of the trees. If moisture is plentiful and sustained, germination takes place without difficulty in the case of pods lying on the surface of the ground, but if there is only occasional rain with intervening dry weather, inducing the swelling of the seed without complete germination, the seed is liable to rot or to dry up. If the pods become buried with the early showers, as they often do in loose soil, successful germination is greatly facilitated. Natural reproduction, both by seed and by root-suckers, is more profuse than in the case of most species on the plains of India, owing to the hardiness of the seedlings, their power of recovery from injury, and their immunity from damage by grazing.

ARTIFICIAL REPRODUCTION. Experiments carried out at Dehra Dun have shown that artificial reproduction may be effected successfully both by direct sowing and by transplanting from the nursery, though the former is undoubtedly the more successful and economical method. In forest operations the young plants suffer greatly from the attacks of pigs and porcupines, and of rats on grass-lands. In places where these animals are prevalent it is almost hopeless to attempt raising plantations of *Butea* unless some means of preventing their depredations can be applied.

Direct sowing. The tree can be raised with great success by line sowings,

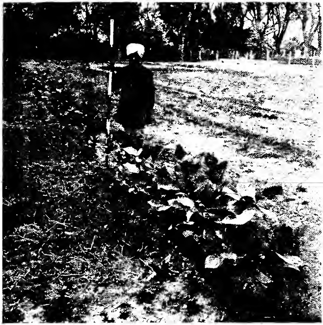

FIG. 105. *Butea frondosa*, irrigated line sowings 6 months old, Dehra Dun. Staff shows feet.

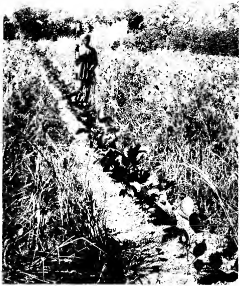

FIG. 106. *Butea frondosa*, line sowings with the aid of field crops Dehra Dun showing plants in second season. Line left unweeded in first year and weeded in second year, crops (lesser millet) being resown. Staff shows divisions of six inches.

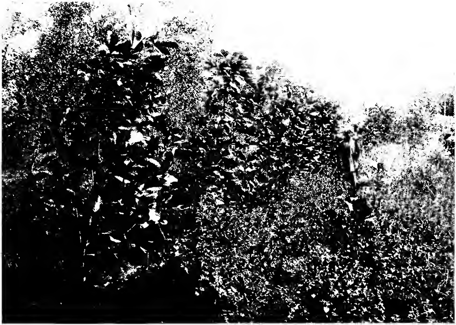

FIG. 107. *Butea frondosa*, irrigated line sowings $3\frac{1}{2}$ years old. Dehra Dun. On left weeded line well stocked with plants up to 12 ft. 9 in. in height; on right, running past base of staff, unweeded line with only a few remaining plants under 2 ft. in height. Staff shows divisions of six inches

both irrigated and unirrigated, with or without the aid of field crops. Whatever method is employed, weeding during the first year or two is essential to the proper development of the plants, while the thinning out of congested plants should be commenced if necessary at the end of the first season and continued regularly. It is unnecessary to extract the seed from the pods, though the wing of the pod may be broken off if desired. The pods should be placed about 10–12 in. apart along the lines and lightly covered with earth: 1 lb. of pods will ordinarily suffice for 250 ft. of line. The seed should be collected before the rains commence, either off the trees or from the ground, and should be sown soon after collection. For ordinary afforestation a distance of about 10–12 ft. between lines will be found suitable: for lac cultivation the trees require to be spaced more widely in order to induce full crowns, and a distance of 20 ft. or more between lines will probably be found sufficient. In irrigated sowings the most satisfactory method is to sow the seeds in the loose soil near the base of the ridge of earth thrown up alongside irrigation trenches, 1 ft. by 1 ft. in section, on the side facing the trench. Figs. 105 and 107 show irrigated line sowings at Dehra Dun, and the latter shows clearly the effect of leaving a line unweeded. For unirrigated line sowing the ground should be ploughed or hoed up to a width of about 1 ft. before sowing. The best results in unirrigated line sowings have been attained in combination with the cultivation of field crops. The crop used for experimental purposes at Dehra Dun was the lesser millet or *mandwa* (*Eleusine coracana*). It was found that if the cereal crop was sown continuously all over the area, although the lines were well stocked, the growth of the seedlings was somewhat retarded by suppression during the first rainy season, though subsequently the growth was good if the lines were regularly weeded. Fig. 106 shows a line treated in this way. Better results were attained by leaving a clear strip 2 ft. wide along the lines, the cereal crops being sown only in the intervening spaces: weeding was carried out by the cultivator while the crops were on the ground.

Agri-silvicultural sowings of *Butea* along with other species of trees have been carried out in Berar, but the *Butea* seedlings suffered greatly from the attacks of porcupines. Where plantations are formed for lac cultivation and a wide spacing of lines is adopted it would be advantageous to cultivate field crops between the lines as long as possible, not only on economic grounds, but also in order to keep the land free of weeds and to assist in protecting the young plants against pigs and porcupines.

Transplanting. Experiments at Dehra Dun have shown that fair success can be attained by transplanting from the nursery during the first rainy season, particularly if the stem is pruned down to about 2 in. and the taproot to about 9 in. Owing to the length of the taproot transplanting with unpruned stem and root is not only more difficult but less successful. Transplants tend to die back during the winter, whether pruning is done or not. In order to raise plants in the nursery the seed should be sown as soon as it is ripe, and as long before the beginning of the rains as possible, in order to obtain sufficiently large transplants before the rainy season is too far advanced. The pods should be placed about 4 in. apart in shallow drills 9 in. apart, and lightly covered with earth. Great care in the preparation of the seed-beds is unnecessary, since the young plants come up well under unfavourable conditions. Regular watering and weeding should be carried out after sowing: the seedlings usually commence to appear in one to two weeks.

POLLARDING FOR LAC CULTIVATION. I recently published details of experiments carried out from 1909 to 1918 at Ranipur in the Saharanpur Siwaliks, the object of which was to ascertain the best method of pollarding *Butea frondosa* trees, and the most suitable rotation to adopt, for the purpose of propagating lac.[1] For the reception of lac it was found that complete pollarding was far preferable to the partial lopping so frequently practised, since not only does it produce a larger number of succulent shoots such as are required to support the lac insect, but the collection of the lac crop is greatly facilitated if all the shoots are lopped off at one time, as this obviates the waste of time, under a system of partial lopping, in searching for lac-covered branches and twigs. The tying up of brood-lac is also much facilitated by complete pollarding, since clusters of pollard-shoots are produced, at the base of which it is easy to place open baskets full of brood-lac for the impregnation of the shoots.

The initial pollarding of trees which have not previously been pollarded should be carried out with a saw, all branches being cut off to a section of about 2 to 4 in. in diameter, and no leafy branches being left: it is not advisable. if it can be avoided, to cut branches of a larger diameter than 4 in., otherwise thick corky pollard-shoots are produced which are avoided by the lac insects. The branches should not all be cut off flush, but occasional stumps about 6 to 8 in. long should be left where required, to facilitate climbing during subsequent pollarding operations. The subsequent pollarding, at the time of collection of the lac crop, should be done with a sharp bill-hook or light axe, the shoots being cut off flush at the base: the pollarding should be complete, no shoots being left on the tree.

As regards the pollarding rotation, the experiments proved conclusively that a rotation of one year is the only satisfactory one to adopt. At Ranipur the swarming of the lac larvae takes place twice a year, early in July and late in October. The trees are pollarded immediately before the swarming and a portion of the lac crop then gathered is used as brood-lac for the next crop. The brood-lac consists of lac-covered twigs cut into pieces several inches long, which are placed in open-work baskets, a number of pieces in each. The baskets of brood-lac are placed or hung up with wire hooks at the bases of the clusters of pollard-shoots produced by the previous lopping: the lac larvae soon swarm over the shoots, after which the baskets of lac are removed. The lac larvae always swarm over the young green portions of the shoots and on the petioles and midribs of the leaves, never on those portions of the shoots which have begun to form corky bark. In the case of the more vigorous shoots this corky bark often begins to form in less than half a year, while in shoots more than a year old the length of new green growth each year is much smaller than it is in pollard-shoots of the first year: consequently with any lengthening of the rotation above one year there is a considerable diminution of the lac-bearing surface on each tree, while in addition the total number of trees available for the reception of lac on a given area is reduced. It follows, therefore, that a pollarding rotation of one year produces a higher yield of lac than any longer rotation.

---

[1] Ind. Forester, xlv (1919), p. 223.

In carrying out annual pollarding in practice the trees on a given area should be divided into two groups; in one group the trees are lopped in July and the pollard-shoots are ready for the reception of brood-lac the following October, while in the other group they are lopped in October for the reception of brood-lac the following July. These dates refer to the locality in which the experiments were carried out, and may require modification to suit other localities.

The effect of the annual pollarding on the vigour of the trees and the pollard-shoots was observed for ten years. There was considerable variation in the number and dimensions of the shoots from year to year, but the average results showed no great diminution in their vitality during the period in question. It may, therefore, be concluded that annual pollarding can be carried out with little or no deterioration in the pollarding capacity of the trees for a number of years, though in practice two safeguards should be adopted, namely: (1) to fix a limit of girth, to be ascertained locally, below which no trees should be pollarded; and (2) to fill up all gaps artificially with young plants. Possibly a minimum girth of 1½ or 2 ft. will suffice generally. At Dehra Dun young *Butea frondosa* plants in weeded line sowings may be expected to attain girths of 1½ ft. in nine years and 2 ft. in twelve years if irrigation is carried out, and girths of 1½ ft. in eleven years and 2 ft. in fifteen years without irrigation. These experiments showed that the yield of lac was greater in the case of trees growing in open positions than of those growing close together, and hence tending operations should include the thinning out of trees where they are crowded.

During the course of these experiments an effort was made to ascertain if steps could be taken to eradicate the various parasitic and predaceous insects which do so much damage to the lac and may destroy the entire crop. Careful observations of the dates of emergence of these insects from samples of lac collected at different times showed that their emergence takes place for the most part shortly after the swarming of the lac larvae in July and October. It was hoped, therefore, that the prompt removal of the brood-lac as soon as the swarming of the lac larvae was over would result in a diminution in the number of parasitic and predaceous insects, and possibly in their extermination, and actually such a course must result in the destruction of large numbers of these insects if precautions are taken to remove all the lac in closed bags. A further precaution would be to collect and burn all twigs from which the lac crop has been gathered and which usually have fragments of lac adhering to them, as well as the leaves, which fall about January to March, since their petioles and midribs are frequently coated with half-formed lac. Actually such a course did not result in any appreciable diminution in the number of parasitic and predaceous insects, though this may well have been accounted for by the fact that indiscriminate lac cultivation is carried on in the neighbourhood, and each brood of lac was probably parasitized afresh from outside. Such a contingency would nullify any efforts to cope with these insects under a system of regular pollarding, which, in order to have a reasonable chance of success, would require to be adopted universally in a given locality.

Rate of growth. So far as available records show the rate of growth of coppice-shoots is fairly rapid, but the girth increment of trees is decidedly slow. Measurements in different coppice coupes near Dehra Dun recorded by Mr. A. F. Broun in 1886 gave the following results in the case of *Butea* as compared with sal in the same coupes :

Age		8 yrs.		8 yrs.		9 yrs.		9 yrs.		10 yrs.	
		ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.
Mean height	*Butea*	17	0	17	0	15	0	14	2	8	0
	Sal	16	3	13	2	13	5	16	0	11	11
Mean girth	*Butea*	0	8	0	7·1	0	13·5	0	9·4	0	2
	Sal	0	8·3	0	7·1	0	8·7	0	8·6	0	5·9

The locality in question is subject to severe frost, which may account for the small size of the shoots in the ten-years coupe if the shoots had been killed back at some period.

The girth increments of trees are exhibited in the following records of periodical measurements in sample plots in the United Provinces:

Butea frondosa : rate of growth of trees, United Provinces.

Locality.	Number of years under observation.	Number of trees.	Girth class. ft.	Mean annual increment for period. in.	Remarks.
Saharanpur division (Dholkhand, Lakarkot. and Maluwala—3 plots)	4, 7. and 12	7	1–2	0·10	In sal forest.
			2–3	0·09	
			3–4	0·16	
Saharanpur division (Ranipur)	3	10	1–2	0·27	In fairly open situation.
Lansdowne division (3 plots)	4, 4, and 17	6	1½–3	0·45	

Under favourable conditions seedlings and saplings grow rapidly, and it is probable that tended plantations would show a very fair rate of growth for some years at least. In irrigated and unirrigated line sowings at Dehra Dun dominant plants seven years old had attained the following girths :

	Irrigated.		Unirrigated.	
	ft.	in.	ft.	in.
Mean girth	1	4	1	1
Maximum girth	1	11	1	3

3. ERYTHRINA, Linn.

This genus comprises seven Indian species with large trifoliate leaves and bright red flowers which in most cases appear in the early part of the hot season when the trees are leafless. Of the Indian species all are trees except *E. resupinata*, Roxb., a dwarf herbaceous species with a perennial root-stock from which are sent up annually racemes of scarlet flowers in the hot season, the leafy shoots appearing subsequently and dying down after the rainy season ; this interesting plant occurs in the annually burnt grass-lands of the sub-Himalayan tract, and the flowers are conspicuous on the ground after the annual fires have overrun these savannah lands.

The tree species have light soft whitish woods which are used for sieveframes, scabbards, domestic utensils, and other purposes. Silviculturally they are interesting from the readiness with which they grow from cuttings, fairly large branches if stuck in the ground taking root and growing rapidly: these cuttings are grown sometimes for live fences and often for supporting betel vines. Some of the species are planted for ornament.

Species 1. *E. suberosa*, Roxb.; 2. *E. indica*, Lam.

1. **Erythrina suberosa,** Roxb. Vern. *Pangra, dhauldhak*, Hind.; *Kathit*, Burm.

A moderate-sized to large deciduous tree with thick corky light grey bark, armed with conical prickles. The tree is scattered in dry forests throughout India and Burma. The trees are leafless as a rule from December to June. The scarlet flowers appear from March to May on the leafless trees, and the pods ripen about June–July. The seedling forms a long very thick taproot, as much as 1 in. in diameter in the first season, like that of *Butea frondosa*. The tree coppices and pollards vigorously, thick prickle-covered shoots being produced; it also grows readily from cuttings. The growth is rapid; a cross-section in the silvicultural museum at Dehra Dun showed 42 rings for a girth of 5 ft. 3 in., giving a mean annual girth increment of 1·5 in. Gamble's specimens showed 4 rings per inch of radius, representing a mean annual girth increment of 1·57 in.

2. **Erythrina indica,** Lam. Indian coral tree. Vern. *Pangra*, Hind., Mar.; *Pinlè-kathit*, Burm.

A moderate-sized tree with small black prickles and smooth greenish yellow bark exfoliating in papery flakes. Indigenous in the coast forests from Bombay to Malabar, from the Sundarbans along the coast through Arakan, Pegu, and Tenasserim, and in the Andamans and Nicobars: much planted for ornament, and sometimes escaped from cultivation. The tree occurs chiefly along raised sandy beaches above high-water mark: in the Andamans its chief associates on these beaches are *Mimusops littoralis, Calophyllum Inophyllum, Thespesia populnea, Terminalia Catappa, Heritiera littoralis. Afzelia bijuga, Pongamia glabra*, and *Hibiscus tiliaceus*. Talbot says that on the Bombay coast it is sometimes associated with *Calophyllum Inophyllum, Salvadora persica, Clerodendron inerme, Grewia Microcos*, and other species. The scarlet flowers appear in April–May, and the pods ripen about June.

4. PTEROCARPUS, Linn.

This genus comprises five species in the Indian region, namely: (1) *P. Marsupium*, Roxb., the kino tree, extending throughout the greater part of the Indian Peninsula and northward to the foot of the central Himalaya; (2) *P. santalinus*, Linn. f., the red sanders, occupying a restricted area in the Indian Peninsula: (3) *P. dalbergioides*, Roxb., the Andaman padauk or redwood, indigenous in the Andaman Islands: (4) *P. macrocarpus*, Kurz, the true or Burma padauk, occurring as a forest tree throughout the greater part of Burma; and (5) *P. indicus*, Willd., the Malay padauk, believed to be indigenous in the Malay Peninsula and Archipelago, and commonly planted along roadsides in Rangoon and other towns in Burma. Of these the first four are important timber trees, while the fifth is a well-known roadside tree in Burma, but is of no importance as a timber tree in that province.

Until Col. Prain published in 1900 his 'Report on the Indian Species of *Pterocarpus*' (*Indian Forester*, xxvi, App.) much confusion existed regarding the identity of the trees to which the name 'padauk' has been given; his paper set at rest the misapprehensions previously existing, and established the fact that there are three distinct species popularly known as 'padauk'. Strictly speaking *P. macrocarpus*, Kurz, indigenous in Burma, is the true padauk tree; the name was applied to the Andaman tree, *P. dalbergioides*, Roxb., by Burmese convicts owing to its resemblance to the padauk tree of their country, while the same name was also given to the introduced tree *P. indicus*, Willd., owing to its general similarity to the wild padauk of Burma.

The trees of this genus are characterized by alternate compound leaves with alternate leaflets, yellow flowers in racemes, usually panicled, and flat orbicular indehiscent one- or two-seeded pods, of which the hard bony centre containing the seeds is surrounded by a wide circular wing. The seeds of all the species have a characteristic shape to which in the descriptions below the term 'dolabriform' is applied as most nearly describing it; the outline resembles that of a broad curved pruning-knife, or a triangle with one short side and two longer unequal sides, the longer of which is concave. Germination is similar in all the species, the radicle (or where there are two fertile seeds two radicles) issuing from the side of the pod opposite the stalk and the pod dehiscing slightly at the point of emergence; this point is strictly speaking the side and not the end of the pod, for as the pod develops from the flower one side grows faster than the other, so that the end is bent round to one side in the fruit and the style is apparently lateral and in some cases quite near the stalk itself.

The members of this genus are essentially trees of warm climates; the hardiest of the Indian species is *P. Marsupium*, which extends to localities where frost is not unknown, and is the only species which has been able to survive the winter at Dehra Dun. The most deciduous species is *P. macrocarpus*, which is leafless for an appreciable length of time; the others are either not leafless for so long or are semi-deciduous or practically evergreen. The four strictly Indian species are not gregarious trees, but occur scattered in mixed, usually deciduous forests, where as a rule they form a comparatively small proportion of the growing stock; they are found most typically on undulating or more or less hilly country, avoiding stiff low-lying clayey ground and requiring perfect drainage.

Species 1. *P. Marsupium*, Roxb.; 2. *P. santalinus*, Linn. f.; 3. *P. dalbergioides*, Roxb.; 4. *P. macrocarpus*, Kurz; 5. *P. indicus*, Willd.

1. **Pterocarpus Marsupium**, Roxb. Kino tree. Sans. *Asana*. Vern. *Bija*, *bijasál*, *piasál*, Hind.; *Bibla*, *asan*, Mar.; *Honne*. Kan.; *Yegi*, *peddagi*, Tel. *Vengai*, Tam.; *Bange*, Coorg.

A large deciduous tree with spreading branches, producing a straight clean bole under favourable conditions. Leaves 7–9 in. long with 5–7 (sometimes 8 ?) coriaceous leaflets. Bark about 0·5 in. thick, grey, exfoliating in small irregular scales; blaze pink with whitish markings, that of older trees exuding a blood-red astringent gum-resin. One of the most important timber trees of the Indian Peninsula, attaining under favourable conditions a height of 100 ft. and a girth of 8 ft. or more. Wood very hard, close grained, heartwood yellowish brown, durable, much used for building, agricultural implements, carts, wheel-work, boats, &c.; the wood stains yellow when damp. The red gum-resin which exudes from wounds in the bark furnishes the 'kino' of commerce, a valuable astringent used in medicine. Prain distinguishes two rather marked botanical varieties of the tree, each containing two somewhat distinct geographical forms.

DISTRIBUTION AND HABITAT. Throughout the greater part of the Indian Peninsula, extending northward to Mount Abu in the west, the Santal Parganas in the east and Bundelkhand in the centre: also in limited quantity in the sub-Himalayan tract, in Oudh, and the Kumaun *bhabar*. In Ceylon it is found in the central parts of the island (Prain). The tree is found scattered in deciduous forests, mainly on hilly ground, at elevations up to 3,500 ft. or sometimes more, but most commonly between 500 and 1,500 ft. In the Central Provinces it is fairly common in Bhandara, Balaghat, Saugor, Chanda, and Damoh, and is more or less scattered or locally common in other districts, but is rare in Berar; it occurs mainly on hilly ground, preferring northerly aspects, its chief companions being teak, *Terminalia tomentosa*, *T. belerica*, *Buchanania latifolia*, *Lagerstroemia parviflora*, *Anogeissus latifolia*, *Acacia Catechu*, *Cleistanthus collinus*, *Butea frondosa*, *Dalbergia latifolia*, and other trees characteristic of the mixed deciduous forests. In Chanda it attains large dimensions. In Bombay it occurs most plentifully in the southern portion of the Presidency, being particularly common in North Kanara and fairly plentiful in Surat and in the Rajpipla state. In the moist climate of North Kanara it affects chiefly the upper parts of ridges where it obtains light and warmth; its chief associates here are teak, *Dalbergia latifolia*, *Xylia xylocarpa*, *Lagerstroemia lanceolata*, *Terminalia tomentosa*, *T. paniculata*, and *Adina cordifolia*. In the Deccan districts it is more scattered; in the Khandesh Akrani it ascends to 3,700 ft. (Talbot). In southern India it occurs in most districts, scattered in deciduous forests associated with teak, *Terminalia tomentosa*, *T. Chebula*, *Dalbergia latifolia*, *Chloroxylon Swietenia*, *Anogeissus latifolia*, *Albizzia Lebbek*, *A. odoratissima*, *Diospyros Melanoxylon*, and other trees, with or without bamboos. In the Nilgiri Wynaad it may in favourable localities form as much as 10 per cent. of the growing stock. It attains its largest dimensions in the south, particularly in Coimbatore, Madura, and Tinnevelly, where trees up to 16 ft. in girth are occasionally met with. In the region of *Pterocarpus santalinus*, that is, chiefly in Cuddapah and North Arcot, the two species occur together, but whereas *P. santalinus* ascends to 3,000 ft. *P. Marsupium* ascends only to 2,500 ft. In the northern parts of the Presidency where, in Ganjam, it is sometimes found in sal forest, it seldom attains large size. In Coorg and Mysore it is common in deciduous forests, and reaches large dimensions. In Travancore it is common in deciduous forests up to 3,500 ft. (Bourdillon). It is one of the most important timber trees of Hyderabad.

In Chota Nagpur and Orissa it is locally common, chiefly on hilly ground in valleys or on northerly slopes, in mixed deciduous forest or in sal forest. Except in parts of Orissa, Sambalpur, and Singhbhum it is usually of small size. In the United Provinces it occurs in limited quantity and of comparatively small size in parts of Bundelkhand and in the sub-Himalayan tract from

Gorakhpur westward to the eastern corner of the Kumaun *bhabar* tract, in dry deciduous forest associated with *Lagerstroemia parviflora*, *Terminalia tomentosa*, *Anogeissus latifolia*, *Holoptelea integrifolia*, *Acacia Catechu*, and other trees. It is absent from the Bengal Duars. It is found scattered in limited quantity and of small size in parts of the Marwar, Rewah, Indore, and Gwalior states.

The tree is characteristic of deciduous types of forest, and appears to grow on a variety of formations provided the drainage is good. It grows both on hilly or undulating country, and on more or less flat ground, preferring a soil with a fair proportion of sand, and is often found on red loam with a certain percentage of clay. It is not exacting, however, since it reaches larger dimensions than most other trees on exposed hill-sides on rocky ground and shallow soil where the forest growth is poor: in such places it is at times almost gregarious. In the Peninsula it is common on gneiss, quartzite, shale, conglomerate, sandstone, and laterite: less common on trap (Haines). In the sub-Himalayan *bhabar* tract it occurs on a deep dry well-drained boulder formation where the subsoil water-level is at a great depth. Foulkes (*Notes on Timber Trees of S. Canara*) says it grows on laterite when there is plenty of moisture in the soil, and will grow well on rocky laterite; also that it is well suited to gneissic soils, but will not grow on the sandy soils of the coast.

In its natural habitat the absolute maximum shade temperature varies from 95° to 118° F., the absolute minimum from 32° to 62° F., and the normal rainfall from 30 to 80 in. or more.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The tree is nearly evergreen, or is leafless for a very short time in the hot season in April–May, the new leaves appearing in May–June. The panicles of fragrant yellow flowers appear from June to September, sometimes later. In the Peninsula the pods ripen from December–January until March–April. In the sub-Himalayan tract they are not ripe till about April. The pods (Fig. 108, *a*) are light yellowish brown, nearly orbicular, 1–2 in. in diameter, the wing flat and stiff, and the central portion, containing one to two seeds, convex and bony. The seeds (Fig. 108, *b*) are dolabriform, 0·4–0·5 in. long, reddish brown, fairly hard, with a smooth shiny leathery testa. The ripe pods hang in clusters on the tree for some time after ripening, most of them falling during and towards the end of the hot season, the strong dry winds prevalent in many localities at that time distributing them to a distance. In good seed-years, which occur at frequent intervals, the pods are produced in great abundance, particularly by trees in open situations; the seeds, however, possess a comparatively low percentage of fertility, and are sometimes much affected by insect attacks.

GERMINATION (Fig. 108, *c–g*). Epigeous. One or sometimes two seedlings are produced from one pod. The radicle emerges from the side of the pod opposite the stalk, at once bending downwards to reach the soil. Either the cotyledons are extricated by the arching of the hypocotyl, the pod being left on or in the ground, or the pod enclosing the cotyledons is raised above ground, falling with the expansion of the cotyledons. The testa of the seed remains within the pod.

THE SEEDLING (Fig. 108).

Roots: primary root long, moderately thick, terete, tapering, wiry to woody : lateral roots moderate in number, fibrous : nodules present. *Hypocotyl* distinct from root, 0·3–0·5 in. long, slightly compressed, tapering down, white, soon turning green. *Cotyledons* sub-sessile or shortly petiolate, foliaceous, somewhat fleshy, 0·9–1·1 in. by 0·4–0·5 in., unequally ovate oblóng, apex and base rounded, entire, green, glabrous, venation arcuate reticulate ; glands present on the hypocotyl between the cotyledons. *Stem* erect, terete, zigzag at the nodes, green, with minute adpressed hairs. *Leaves* alternate, petiolate, first five or six simple, usually followed by several trifoliate, then 4- or 5-foliate and finally 7-foliate leaves ; 5-foliate leaves begin to be produced in the second season in vigorous plants. Stipules 0·15 in. long, linear lanceolate, acuminate. Simple leaves with petiole 0·2–1 in. long, channelled above, with minute adpressed hairs ; lamina 0·6–3 in. by 0·4–2 in., broadly ovate acuminate, mucronate, base obtuse or cordate, entire, glabrous above, pubescent beneath, lateral veins 6–10 pairs ; first two leaves smaller than subsequent leaves. Trifoliate leaves with rachis 1·5–3·5 in. long ; leaflets alternate, with short petiolules up to 0·1 in. long, ovate or elliptical, apex acute or rounded or retuse, mucronate, base rounded, entire, glabrous above, pubescent and paler beneath ; terminal leaflet 2·5–3·5 in. by 1·4–2·5 in., lateral leaflets 1·5–2·8 in. by 1–2·2 in.

The development of the seedling during the first year is comparatively slow, a height of about 2 to 6 in. being attained by the end of the first season under natural conditions, though in seed-beds regularly watered and weeded a height of as much as 3 ft. or more may be reached. During the second season the growth is faster, a height of about 2 to 5 ft. or more being attained under favourable natural conditions and as much as 5 to 8 ft. or more in the case of plants regularly watered and weeded. A long taproot is produced at an early stage, the taproot sometimes reaching a length of 1 ft. in the first month. Natural forest seedlings may show little stem development or may die back annually for several years, ultimately shooting up after they have developed a long stout taproot. Although the seedlings are capable of struggling successfully against a moderate growth of low weeds and grass their development is greatly stimulated by weeding and loosening of the soil. They are very frost-tender, suffering particularly amongst grass and less so in beds kept weeded and watered. They are also sensitive to drought in their earlier stages, and benefit by side protection from the sun on dry ground. During germination the radicle is very liable to dry up before reaching the soil if the pods are lying on the surface of the ground exposed to the sun, and the seedling almost invariably perishes : under shade and in comparatively moist situations, however, the young root has the power of creeping along the ground for some distance and retaining its vitality until it finds an opportunity of penetrating the soil. This vitality of the young root during and immediately after germination in places not exposed to drought is noticeable in the case of pods falling amongst grass and weeds and suspended an inch or two above ground ; here in moist situations germination takes place and the young root is for a time aerial until it reaches the soil, the cotyledons being capable of providing nourishment in the meantime. The radicles of germinating seedlings are much subject to the attacks of insects, but unless the damage is severe the seedling is capable of surviving. Although germination can take place under dense shade the seedlings will not survive and develop except under comparatively light shade. Young plants are much subject to browsing by cattle, goats, and deer.

SILVICULTURAL CHARACTERS. The tree is a moderate light-demander. Seedlings and saplings are capable of pushing their way through shrubby growth, and saplings and poles can stand a fair amount of lateral shade but will not tolerate any but the slightest overhead shade. Complete freedom overhead is necessary for proper development from the pole stage onwards. Young plants are frost-tender. In the abnormal drought of 1899 and 1900 trees suffered rather severely in the drier parts of the Peninsula. The tree produces root-suckers, as a rule sparingly. It usually coppices fairly well. Experiments carried out in North Chanda in 1909 showed that both in coppicing and in pollarding capacity it was inferior to the teak and far inferior to *Lagerstroemia parviflora*: if anything it was found to pollard better than to coppice. As regards the best season for coppicing, these experiments gave the following percentage of success where the coppicing was done in different consecutive months—April, 100 per cent.; May, no stools; June, 100 per cent.; July, 33 per cent.; August, 0 per cent.; September, 0 per cent. In some localities, particularly in Indian states, the trees have been extensively damaged by lopping for cattle fodder.

NATURAL REPRODUCTION. Under natural conditions germination starts early in the rainy season, and the two most important factors which favour the early development of the seedling are a loose soil clear of weeds in which the pods become wholly or partially buried by the early showers of rain, and shelter from the heat of the sun; for the latter reason seedlings may be found establishing themselves, even in dry exposed places, behind the shelter of rocks, stones, clods of earth, bushes, &c. It has already been mentioned that where the pods are lying on the surface of the ground the radicles of germinating seeds, if exposed to the sun, are liable to dry up; this is a common cause of mortality in dry places and on stiff soils, particularly when a break in the rains occurs in the early part of the monsoon. Where the pods fall among weeds or thick grass germination may, as already stated, take place an inch or two above ground-level, the young root surviving for some time and in some cases reaching the soil: under such conditions, however, the percentage of mortality is high, for the root tends to rot in moist places and to dry up in dry places. Natural reproduction is sometimes good in grassy areas, and in dry places it may be found in the form of thickets under the moderate shade of other trees.

Most of the pods fall in the hot season and are liable to be damaged by fire unless fire-protection is enforced. Grazing is very inimical to successful reproduction, seedlings being practically absent in heavily grazed areas. Small plants which have been repeatedly burnt back or grazed are often found with a thickened root showing several years' growth. Measures possible for stimulating natural reproduction are the exclusion of fire and grazing, hoeing the soil where seed-bearers are present, and gradually freeing the young plants from overhead cover when they become established.

ARTIFICIAL REPRODUCTION. Owing to the hardness of the pods germination is a matter of some difficulty, and the percentage of success is comparatively low. Experiments at Dehra Dun have shown that germination can be hastened to some extent by soaking the pods in water for a few days prior to sowing; it is still further hastened if, before soaking, the ends of the pods are cut across sufficiently to admit the water into the pod. Germination can also be stimulated by placing alternate layers of pods and dead leaves in a pit, which is then flooded with water: as soon as germination starts the pods are removed and sown in the nursery. The extraction of the seeds is a tedious matter, but they germinate in a few days if extracted and soaked prior to sowing. If the pods are sown without soaking germination ordinarily starts in two to four weeks.

Direct sowing has proved more successful than transplanting from nursery beds. If transplanting with entire roots and stems be carried out this should be done early in the first rains when the seedlings are still small, and even then great care is necessary. Experiments at Dehra Dun in transplanting seedlings both in the first and in the second rains, after pruning the taproot down to about 8 in. and the stem down to near ground-level, met with only partial success. To raise plants in the nursery the pods should be sown about March or April in drills 9 in. apart in well-raised beds with a porous soil of light sandy loam, regular weeding and watering being carried out. The most successful method of transplanting is to raise the seedlings in bamboo baskets and plant them out in the baskets. Direct sowings are best done in lines, as weeding is thereby facilitated. Line sowings with the aid of field crops should afford suitable protection against the sun, clear lines about 2 ft. wide being left, with the crops in the intervening spaces.

Plantations require careful protection in their younger stages from fire and grazing and from damage by deer.

SILVICULTURAL TREATMENT. In existing working plans the tree is as a rule worked either by selection fellings or as standards in coppice-with-standards. In selection fellings sound trees are ordinarily felled when they reach a girth of 6 ft. or a diameter of 2 ft.; where large dimensions are obtainable, as in Madura, Belgaum, &c., a girth limit of 7 ft. is fixed. Under ordinary conditions its silvicultural treatment would be combined with that of teak, blackwood, and other valuable species, regenerative operations in high forest consisting of the gradual removal of the overwood over established young growth, the opening of the canopy to stimulate new reproduction, with hoeing of the soil if necessary, and the weeding and cleaning of the young crop. Where natural reproduction fails sowing or basket planting would have to be resorted to.

RATE OF GROWTH. Mr. A. Rodger[1] quotes the case of a tree planted at Chaibassa which reached a height of 20 ft. and a girth of 10 in. in ten years: he also cites the case of a plantation in Central Coimbatore thirty years old which contained about 200 trees in excellent condition up to nearly 7 ft. in girth.

Periodic measurements of ten trees for seven years in the Walayar reserve, Coimbatore, Madras, showed a mean annual girth increment of 1·5 in. for the period: the trees varied from 1 ft. 7 in. to 3 ft. 1 in. in girth at the beginning of the period. This indicates a fairly rapid rate of growth.

Certain working plans give estimates of rate of growth based on ring countings: it is somewhat doubtful, however, to what extent such estimates can be relied on, as the rings are difficult to determine, and indeed the working plan officer of the North Kanara plan, Mr. Pearson, admits the difficulty of arriving at an accurate estimate. The following figures based on ring-countings may be quoted :

---

[1] For. Bull. No. 17.

Pterocarpus Marsupium : rate of growth in high forest, **North Malabar.**

Diameter.	Average age. Begur forests.	 Chedleth Range forests.
in.	years.	years.
6	36	33
12	69	62
18	106	92
24	144	124

Pterocarpus Marsupium : rate of growth in high forest, **North Kanara.**

Age.	Mean diameter. Kalinaddi slopes forest.	 Ankola high forest.
years.	in.	in.
10	1·9	1·65
20	3·5	3·41
30	5·4	5·41
40	7·3	7·44
50	9·1	9·27
60	10·7	11·24
70	12·4	12·35
80	13·8	13·88
90	15·4	15·56
100	16·9	17·20
110	18·5	18·57
120	19·9	19·54
130	21·2	19·73
140	22·2	22·12
150	23·3	24·32
160	24·0	26·30
170	25·3	27·20

Measurements made in 1916 in the Saitba coppice coupes, Kolhan, Bihar and Orissa, on poor hilly ground, gave the following results :

Pterocarpus Marsupium : rate of growth of coppice, Saitba.

Age.	Mean height.	Mean girth.	Age.	Mean height.	Mean girth.
years.	ft.	in.	years.	ft.	ft.
2	4·0	2·0	10	18·3	8·7
4	8·6	4·0	12	21·0	10·0
6	12·0	5·7	14	23·3	11·0
8	15·0	7·3			

2. **Pterocarpus santalinus,** Linn. f. Red sanders. Vern. *Lal chandan, chandana-maram,* Tam. ; *Yerra chandanam,* Tel.

A small to moderate-sized deciduous tree with an erect bole and a rather dense rounded crown. Leaves 4–7 in. long ; leaflets coriaceous, three, rarely four or five. Prain notes that leaves having more than three leaflets are always the ultimate leaves of their twig. Bark blackish brown, divided into rectangular plates by deep vertical and horizontal cracks, exuding a red juice when cut. Under natural conditions the tree attains a girth of 3 to 5 ft. and a height of 30 to 35 ft., though in plantations on rich ground a height of 50 to 60 ft. would probably be attainable. Wood extremely hard, dark red to almost black.

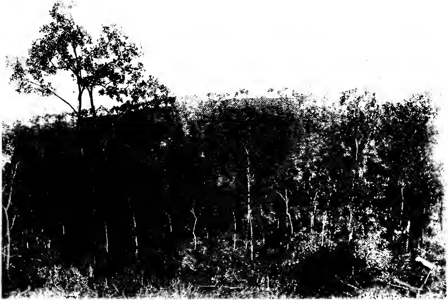

FIG. 109. *Pterocarpus santalinus* forest in South Cuddapah in which felling of badly-shaped stems has been completed, leaving the better trees.

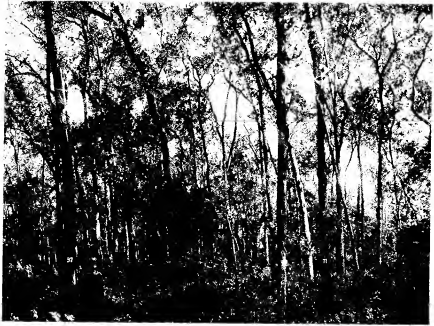

FIG. 110. *Pterocarpus santalinus* plantation of 1865 at Kodur, South Cuddapah, age 52 years

formerly used as a dye, now largely used for carving and ornamental work, and much in request for carved house-posts.

DISTRIBUTION AND HABITAT. The red sanders has a very restricted natural range, extending over an area of only about 6,000 square miles in the south-eastern portion of the Indian Peninsula. It is found chiefly in the Cuddapah district, extending a short distance into the adjoining districts of Kurnool, North Arcot, and Nellore, with an outlier in the Kambakkam and Nagalapuram hills of Chingleput; it does not extend into the Anantapur district to the west of Cuddapah. Its principal home is in the Palkonda or Seshachellam hills of Cuddapah and North Arcot.

In its natural state the tree grows typically on dry hilly, often rocky ground, at elevations of 500 to 3,000 ft. above sea-level; it is sometimes found on precipitous hill-sides. It requires perfect drainage, and is found mainly on stony or gravelly soil on formations of gneiss, quartzite, shale, or laterite: the tree grows particularly well on lateritic loam. On the higher hills it occupies chiefly northern and eastern aspects, but on low hills it is found on all aspects. It will not tolerate stiff water-logged soil, but has been planted with success on rich alluvial ground.

For some years prior to the reservation of the more important red sanders tracts the tree had been declared a reserved tree, and thus escaped the destruction meted out to almost all other species in accessible situations through indiscriminate felling or lopping for manure. In 1883 the aspect of the red sanders forests was described as that of a rocky stony country covered with tufts of lemon grass and with poles of red sanders at intervals of a few yards.[1] Since then these tracts have been reserved and the forest growth has improved considerably.

Among the more typical associates of the red sanders are *Pterocarpus Marsupium*, *Chloroxylon Swietenia*, *Terminalia Chebula*, *T. tomentosa*, *Hardwickia binata*, *Albizzia Lebbek*, *A. odoratissima*, *Dalbergia latifolia*, *Buchanania latifolia*, *Lagerstroemia parviflora*, *Anogeissus latifolia*, *Acacia Sundra*, *A. leucophloea*, and locally *Shorea Tumbuggaia*.

Mr. T. A. Whitehead[2] says that in the south of the Cuddapah district in the southern part of the Seshachellam hills the proportion of red sanders is small, usually about 10 per cent., but the size and quality of the trees are superior to those of trees found in other parts of the district, where the percentage is greater, the tree usually forming over 30 per cent. of the stock and in places growing pure.

Fig. 109 shows a typical natural red sanders area in South Cuddapah, in which a thinning has just been carried out, all misshapen stems having been cut back and the better trees left.

In its natural habitat the tree experiences a comparatively dry hot climate. The absolute maximum shade temperature is about 113° to 116° F. or possibly more, the absolute minimum about 45° to 55° F., and the normal rainfall about 35 to 42 in. Rain is received both from the north-east monsoon (October to December) and from the south-west monsoon (May to September): during the hot months February to May there is little or no rain, and the climate is excessively dry.

---

[1] Ind. Forester, ix (1883), p. 354.

[2] Note on Red Sanders. For. Bull. No. 34, 1917.

Leaf-shedding, flowering, and fruiting. The leaves are shed from January to the middle of March, the leaf-fall taking place earlier in dry than in moist localities: the tree is leafless or nearly so for a short time, the new leaves appearing early in April. The short racemes of yellow flowers appear from April to June; the pods form rapidly, but do not ripen till next February or March. The pods (Fig. 111, *a*) are 1·4–1·8 in. in diameter including the wing, obliquely orbicular, gradually narrowed into a short stalk, brown when ripe: central portion containing the seeds hard and bony. Seeds one or two, 0·4–0·6 in. long, dolabriform, reddish brown, with a smooth leathery testa. About 25 to 40 dry pods weigh 1 oz. The pods fall for the most part during the hot season, chiefly in May. In the Report of the Forest Department for the year ending June 30, 1909, it is stated that trees fourteen or fifteen years old in Napier's Park, Ganjam, seeded twice during the year, and that the seed germinated well on both occasions.

Germination (Fig. 111, *b–g*). Epigeous. The radicle emerges from the side of the pod opposite the stalk. Sometimes—particularly when two seedlings emerge from one pod—the pod is raised above ground, falling with the expansion of the cotyledons: otherwise the cotyledons are extricated by the arching of the hypocotyl, the pod being left on or in the ground. The testa of the seed is always left within the pod.

The seedling (Fig. 111).

Roots: primary root long, moderately thick, terete, tapering, wiry to woody: lateral roots moderate in number, fibrous, distributed down main root: nodules present. *Hypocotyl* distinct from root, 0·4–1 in. long, slightly compressed, fusiform or tapering up or down, white turning green. *Cotyledons* sub-sessile or with petioles up to 0·06 in. long, foliaceous, somewhat fleshy, 0·8–1 in. by 0·3–0·45 in., unequally ovate oblong, entire, apex rounded, base rounded or sagittate or semi-sagittate. *Stem* erect, wiry, green, pubescent; internodes 0·3–1 in. long in natural seedlings. *Leaves* alternate, petiolate, normally all simple during first season, subsequent leaves trifoliate. Stipules linear lanceolate or sub-falcate, acuminate, pubescent. Simple leaves with petiole 0·1–0·5 in. long, channelled above, pubescent; lamina 0·4–1·8 in. by 0·4–1·8 in., cordate, acute rounded or emarginate, mucronate, entire, glabrescent above, pubescent below, venation arched reticulate.

A detailed study of the seedling in its natural home has not yet been made. From numerous specimens received from Cuddapah it would appear that under natural conditions a height of about 4–6 in. is ordinarily attained by the end of the first season, a long taproot being developed. Experiments at Dehra Dun showed that the seedlings are capable of making their way successfully through a moderate growth of grass and weeds, but that weeding and loosening of the soil stimulate their development. As in the case of *P. Marsupium*, when the pods are lying uncovered on the surface of the ground the radicles are apt to dry up during germination if exposed to a hot sun, and are also subject to insect damage; there is far less mortality where the pods are covered with earth. Frost is unknown in the natural habitat of the tree; at Dehra Dun seedlings have invariably been killed by frost in the winter. The seedlings, like those of several other Indian trees, in their natural state die back in dry seasons, but the root-system is unaffected and new shoots are subsequently produced; this dying back may be repeated annually for a series of years until the plants are strong enough to produce permanent shoots.

Silvicultural characters. The red sanders is a light-demander, and will not tolerate overhead shade. Experience gained in the Kodur plantation, described below, shows that an abundance of growing space and room for crown development is necessary for the proper growth of the tree; in other words, regular thinnings are required to promote the best growth. It is not exacting as regards soil, being often found on poor dry shallow soil, though naturally it shows better growth on rich soil; perfect drainage, however, is essential. It coppices vigorously and produces root-suckers freely. It resists fire well, even seedlings escaping serious damage better than most species. Young plants are readily browsed by cattle and deer.

Natural reproduction. The conditions favouring natural reproduction require further study, but so far as experiments at Dehra Dun go the ideal conditions would appear to be similar to those which favour the reproduction of *P. Marsupium*, namely, a loose soil, in which the pods become wholly or partially buried, and shelter from the heat of the sun in the germinating and seedling stages. Under natural conditions germination takes place in the early part of the south-west monsoon, and as a rule the seed germinates readily and natural reproduction is easily obtained in areas protected from fire and grazing; the young plants benefit by protection from the sun in hot places.

Artificial reproduction. So far little experience has been gained in raising plantations by direct sowings. Such experiments as have been made show that there is considerable risk of mortality by drought in the early stages, and it is possible that the system of sowing along narrow cleared lines with field crops in the intervening spaces may prove successful, the crops affording the necessary side shelter: this system is described under *Dalbergia Sissoo*.

The method of basket planting has so far proved the most successful, and appears to have been the one most generally employed in the case of the small plantations which have been made in different localities from time to time. The method, as described by Mr. H. H. Yarde,[1] is to raise seedlings in seed-beds and to transplant them when about one year old into bamboo baskets 1 ft. deep and 9½ in. in diameter: great care is necessary to lift the seedlings with earth round the roots and without damaging the taproot, this being done with the aid of a long-bladed pointed iron instrument known as a *tunkar*. The baskets are placed under shade and watered regularly every second or third day, and the basketed plants are then put out in prepared pits in the rains, preferably in July. Regular weeding is necessary, as well as watering in dry weather for the first few years. In the early stages it is advisable to shelter the young plants from the sun in hot weather; this has been done by fixing leafy branches round each plant and tying them at the top; Peruvian cotton grown in the plantation has also been found to give effective shelter. According to Mr. Yarde a distance of 12 to 15 ft. between plants has been found to give the best results.

The best known red sanders plantation is that at Kodur in the Pullampet valley, Cuddapah district, formed in 1865 by the system of basket planting just described. This plantation, which is situated on rich alluvial soil, was originally 20 acres in area, but has been extended subsequently; in 1912 the area of well-established red sanders of the original plantation was estimated to be 15 acres. The history of this plantation shows very forcibly the need for regular thinnings; in the earlier years the plantation was carefully tended and the growth was rapid, an average annual girth increment of about 1 in. having been recorded during the first eighteen years; subsequently, however, thinnings were neglected, and the average annual girth increment fell to considerably less than half this rate, the dominated trees showing an average total increase of not more than 1 in. for the twenty-nine years 1883 to 1912. The density of the plantation in 1912 can be imagined from the fact that in a sample area in which periodic measurements had been made there were no fewer than 270 trees per acre, a density far too great for a species so intolerant of crown suppression. Fig. 110 shows a portion of this plantation in 1917, when fifty-two years old.

---

[1] Ind. Forester, ix (1883), p. 137.

The tree grows to some extent from cuttings, provided these are kept well watered.

Silvicultural treatment. In the natural forests the most suitable silvicultural treatment is suggested by the readiness with which natural reproduction springs up in areas protected from fire and grazing and establishes itself if sufficient light is afforded. This would indicate that the most satisfactory method of regenerating the forests would be to protect them carefully and to confine regenerative operations to definite periodic blocks, freeing all existing young growth, thinning pole and sapling crops, opening the canopy to stimulate further reproduction, and carrying out works of artificial reproduction where required; in blocks not under regeneration thinnings in favour of red sanders and other valuable species, together with the removal of mature or deteriorating stock, would be necessary. It is not yet certain what would be the most suitable rotation or regeneration period to adopt, but judging from existing records of rate of growth, it is probable that in regularly tended crops under forest conditions a rotation of about sixty years will suffice, and this might be conveniently divided into three or four regeneration periods of fifteen or twenty years each.

Owing to the partially ruined condition of the red sanders forests the system provisionally adopted hitherto has been that of thinnings (improvement fellings) combined with strict protection, extraction being confined to dead, unsound, and misshapen trees (see Fig. 109).

Rate of growth. Statistics regarding the rate of growth are at present somewhat fragmentary. As already stated, the Kodur plantation of 1865, on rich alluvial ground, showed an average annual girth increment during the first eighteen years of about 1 in.; during the following twenty-nine years, in consequence of overcrowding, the maximum rate of growth was only 0·65 in. per annum. In 1881, the plantation being then sixteen years old, Dr. Brandis estimated that it had a volume of 2,400 cub. ft. per acre and was producing an annual volume increment of 150 cub. ft. per acre. In 1883 (age eighteen years) the trees in this plantation had a mean height of 40 ft. and a mean and maximum girth of 18 in. and 30 in. respectively.[1] In 1915, when the plantation was fifty years old, the largest tree in it had a girth of 52 in. A sample plot measured in 1917 had 218 stems with an estimated volume of

---

[1] Ind. Forester, ix (1883), p. 357.

1,710 cub. ft. per acre (see Fig. 110). Mr. P. M. Lushington records that in a plantation in Chittoor, believed to have been formed not later than 1863, the largest tree measured by him in 1912–13, the plantation being then at least fifty years old, had a girth of 48 in., and there were other trees nearly as large.

In natural forest the mean annual girth increment is usually considered to vary from 0·5 to 0·75 in. Mr. Whitehead [1] says a seedling tree commences to form heartwood at the age of about eighteen years, when it has attained a girth of 6–9 in. at breast height, while a coppice-shoot shows signs of forming heartwood at an age of fifteen years, when it has attained a girth of 9–15 in. A premature deposit of the red colouring principle santalin is often found round injured parts. He says a tree seventy to eighty years old, which as a rule averages 40–50 in. in girth at breast height, may be said to have attained exploitable age, that is, the age at which it is capable of yielding a special house-post.

3. **Pterocarpus dalbergioides,** Roxb. Andaman redwood, Andaman padauk. (This is the correct Hunterian spelling of the word, which is often wrongly spelt 'padouk'. The pronunciation of the diphthong *au* is as in 'how' or 'now': the first syllable is short.) Vern. *Padauk,* Burm. (in Andamans); *Chalanga-da, da,* And. (Fig. 112.)

A very large semi-deciduous or practically evergreen tree with ascending branches, attaining a height of 80–125 ft. with a clear bole of 20–50 ft. and exceptionally up to 60–80 ft., and a girth sometimes reaching 18 ft. Leaves 8–10 in. long with five to nine leaflets. The bole is often much buttressed at the base, particularly on low-lying ground and on shallow dry soil, while large over-mature trees are usually unsound. Many of the older padauk trees, which have evidently grown up in a fairly open situation, are crooked in the bole and branch low down.

The wood is moderately hard, the colour of the heartwood varying from light greyish brown to bright red or a rich reddish brown streaked with darker markings: the paler coloured wood is known on the market as 'off colour' padauk, and has a lower market value than the red wood. Whether or not these variations in colour, which are of much economic importance, are due to any external conditions has not yet been determined; they are not accompanied by any variation in botanical characters.

The padauk is the principal timber tree of the Andamans, the red wood being highly esteemed for furniture, railway carriages, billiard tables, panelling, and interior building or decorative work generally: it has gained a footing on the European and American markets, and is in considerable demand. The wood of the buttresses is usually of excellent colour and beautifully figured: one such buttress yielded an oval table 12 ft. 9 in. long by 7 ft. broad, which was in the possession of the late Lord Kitchener.

This is not the true padauk tree, which is *P. macrocarpus,* Kurz, the Burma padauk; the Andaman tree received its name from Burmese convicts owing to its generic similarity to the tree they knew in their own country.

Distribution and habitat. Throughout the Andaman Islands. Very scarce in Great Coco, just north of North Andaman (Prain). Not known in the Nicobar Islands, Narcondam, or Barren Island. The total area of the Andaman Islands being under 2,000 square miles, it has a more restricted distribution than any other Indian tree of the same importance. It has been cultivated to a small extent in Bengal, southern India, and Burma.

---

[1] *loc. cit.*

The tree is not gregarious, but is found scattered in mixed deciduous or semi-evergreen forests from near sea-level up to about 300 ft. elevation, growing best on the well-drained lower slopes of the hills and in the broader valleys, where it is often found along the tidal creeks just above the mangrove belt, which may be only a few yards wide or may extend to a width of a mile or more. Above the padauk belt, and covering the upper slopes and tops of the hills, dense evergreen forest occurs. In the portions of the South Andaman and other islands explored by Mr. Rogers padauk forest was estimated to occupy only about 30 per cent. of the total forest area, while in the North Andaman Mr. Todd estimated that some [illegible] per cent. of the area was occupied by padauk forest, the remainder consisting of evergreen forest and mangrove swamps.

As regards the factors determining the local distribution of the padauk and evergreen forest, Mr. F. H. Todd [1] notes regarding the North Andaman that the underlying rock does not exercise any influence, since it shows little variation throughout the island, consisting as it does of sandstone and conglomerate with intrusive rock, chiefly serpentine in one locality; nor can the depth of soil have much influence, since although padauk does occur on flat ground with deep soil, the finest trees are invariably found on well-drained sheltered slopes, and it will grow on hill-sides even where the soil is very shallow. Altitude, again, need hardly be considered, since the difference in temperature at sea-level and 300 ft. is practically imperceptible. It is probable that the existence of padauk, at all events in the North Andaman, is dependent on the degree of shelter afforded to it, that is, on aspect and situation. Thus it is usual to find on all areas along the coast which are exposed to the south-west monsoon a covering of dense evergreen forest unproductive of padauk, and a short distance behind this protective evergreen belt rich padauk-bearing forest is often found. In sheltered valleys, again, padauk grows at a higher altitude than in exposed situations, where padauk is rarely found at all. Among other specific examples Mr. Todd quotes the case of the country lying between the main watershed and the west coast of the North Andaman Island, which is on the whole flat, with the exception of occasional isolated knolls and ridges rising 200 to 300 ft. above the surrounding country: on the flat ground padauk forest is found, but on the exposed knolls and ridges, although the underlying rock is the same, nothing but evergreen forest unproductive of padauk occurs.

As regards the South and Middle Andaman and other islands, where the geological formation varies from place to place, Mr. Rogers [2] notes that the underlying rock exercises a decided influence on the relative distribution of the padauk-bearing and the evergreen forest. Thus the semi-deciduous padauk forest is never found where the underlying rock is the grey, usually soft, non-

---

[1] Draft Working Plan for the Forests of the North Andaman, 1906; also Ind. Forester, xxxii (1906), p. 581.

[2] Report on the Exploration of the Forests of the South Andamans and other Islands, 1906, paras. 20 and 21.

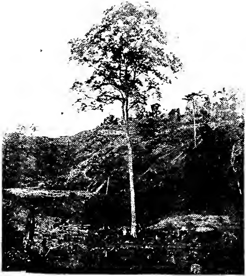

FIG. 112. *Pterocarpus dalbergioides.* Andamans.

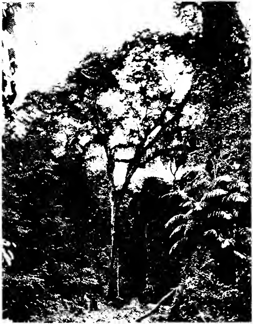

FIG. 113. *Pterocarpus dalbergioides* in semi-evergreen forest, Andamans.

calcareous micaceous sandstone of the Port Blair series; this geological formation supports evergreen forest. The padauk-bearing forest is, with certain exceptions, always associated with the series of rocks termed the Baratang beds, which are often metamorphosed and consist typically of indurated clays and shales, conglomerate, blocks of quartzite, crystalline limestone, and hard coarse-grained non-micaceous sandstone. Again, in the padauk-bearing forest itself the associate species themselves depend to some extent on the nature of the soil: where patches of sandy soil occur evergreen species are found, and as the proportion of clay increases these give way to deciduous trees.

The padauk is associated with various other species of trees, some deciduous and some evergreen, the more important of which are *Lagerstroemia hypoleuca* (chiefly on low ground, rarely on hills), *Terminalia bialata*. *T. Catappa* (on sandy soil and often near the sea-shore), *T. Mannii*, *Albizzia Lebbek*, *Bombax insigne* (chiefly on lower slopes), *Sterculia* spp., *Careya arborea*, *Odina Wodier*, *Artocarpus Chaplasha* (chiefly on the hills), *A. Lakoocha*, *Adenanthera pavonina* (on sandy soil and often near the sea-shore), *Diospyros Kurzii* (on the hills), *Planchonia andamanica*, and *Mimusops Elengi*. Two more or less distinct types of padauk-bearing forest are distinguishable; these may be termed the deciduous and the semi-evergreen types. The former, which is perhaps more typically represented in the North Andaman, is characteristic of hot southern aspects, and the trees are largely if not entirely deciduous: the semi-evergreen type, which occurs on cool northerly aspects and in damp localities, includes besides deciduous trees certain evergreen species characteristic of the evergreen forests, such as *Dipterocarpus* spp., *Hopea odorata*, *Mesua ferrea*, and others.

In the deciduous forests the undergrowth consists mainly of young tree species, thorny creepers, and occasional shrubs. In the semi-evergreen forests the undergrowth is denser, consisting partly of canes (*Calamus andamanicus* and *C. pseudo-rivalis*) and scandent bamboo (*Dinochloa andamanica*) with pure bamboo forest (*Oxytenanthera nigrociliata*) in parts. Fig. 113 shows a padauk tree in semi-evergreen forest.

Mr. Rogers[1] describes a special type of padauk-bearing forest on diluvial deposits formed by the detritus brought down by streams when in flood: these deposits, consisting of deep sandy soil, are often found behind the mangrove swamps and between them and the hills beyond. The forest on these deposits partakes of the characters both of the padauk-bearing and of the evergreen types. Near the mangrove swamps and within the influence of the high spring tides the growth consists of *Phoenix paludosa*, *Licuala peltata* and *L. spinosa*, *Heritiera littoralis*, *Areca triandra*, and *Cynometra ramiflora*. Beyond the influence of the tide padauk occurs along with several of its common associates, the forest trees standing over a dense tangled growth of canes, creepers, climbing bamboos, and two species of *Daemonorops* (*D. Kurzianus* and *D. Mannii*) along with various canes of the evergreen forest, such as *Calamus andamanicus*, *C. tigrinus*, *C. palustris*, *C. gracilis*, and others. The presence of padauk in this type of forest does not necessarily imply its presence in the hills beyond, which may be covered with evergreen forest; in this case

[1] *loc. cit.*, para. 26.

Mr. Rogers considers it probable that the padauk seed was originally brought on to the area by the tides.

In the padauk-bearing forest padauk is as a general rule the predominating species, but the canopy is usually open, and the number of trees per acre is not great. Mr. Todd's enumerations in the North Andaman showed an average of 202 sound padauk trees over 3 ft. in girth per 100 acres. From Mr. Rogers's enumerations in the South Andaman and other islands the average number of sound trees of all species 6 ft. in girth and over was estimated to be 197 per 100 acres, of which padauk numbered 93 and its associates 104 trees per 100 acres; including sound and unsound trees the estimate showed an average of 135 padauk trees 6 ft. in girth and over per 100 acres.

More recent enumerations by Mr. Bonig, combined with Mr. Todd's figures for the North Andaman, have yielded the following estimate of padauk trees existing in 1914:[1]

Pterocarpus dalbergioides: estimate of trees in the Andamans forests in 1914.

	Area of padauk-yielding forest.	Estimated number of padauk trees in girth class.						
		Unsound.	Sound.					
Locality.	acres.	7½ ft. and over.	9 ft. and over.	7½–9 ft.	6–7½ ft.	4½–6 ft.	3–4½ ft.	1½–3 ft.
North Andaman felling series .	98.464	35,171	21,414	21,571	39,756	32,572	23.366	29,872
Middle Andaman felling series .	108,625	68,947	45,901	43,718	46.107	39.063	24.112	18,458
South Andaman felling series .	71,823	71,368	8,298	6,726	10,791	17.019	16,891	20,627
Total .	278,912	175,486	75,613	72,015	96.654	88,654	64,369	68,957
Estimate per 100 acres .		63	27	26	35	32	23	25

A noticeable feature of the padauk forests is the preponderance of mature and over-mature padauk trees, the younger age-classes being inadequately represented or in some cases entirely absent. Seedlings may often be found under seed-bearers during the rains, but except where the cover is very light they disappear before next year owing to suppression, and it is only in places where clearings have admitted light that established saplings and young poles are to be found in any quantity. Mr. B. B. Osmaston[2] notes that this remarkable disparity in the age-classes can be explained only by assuming that there has been a recent change in the condition of the vegetation in the Andamans, the conditions under which the existing crop of mature and over-mature trees arose having given place to others unsuitable to the successful reproduction of the padauk; this change possibly consists in an increase of moisture favouring shade-enduring species to the detriment of padauk. Whatever the precise causes may be, the fact remains that the young crop of padauk is hopelessly inadequate to take the place of that which is now ripe for removal.

As regards the climatic conditions under which the padauk grows in its natural habitat, the absolute maximum and minimum temperatures at Port Blair are 99° and 60° F. respectively, and the normal rainfall is 118 in. At

---

[1] Working Plan Report of the Andamans Forest Division, 1916.

[2] Ind. For. Records, vol. i, pt. iii.

Wimberleyganj, five miles distant, the rainfall is 169 in. : in the North Andaman Island it is probably somewhat less than at Port Blair, since the forests are of a drier type than in the south of the group. The great bulk of the rain falls during the south-west monsoon from May to October ; a fair amount falls during November, December, and April, but little or none from January to March. The climate is damp for the greater part of the year.

FLOWERING AND FRUITING. The yellow flowers in large panicles, which are terminal, or axillary only towards the ends of the branches, appear in the rainy season about June. The pods (Fig. 114, *a*) commence forming rapidly, and ripen the following January to March : when ripe they are dark reddish brown, 1·8–2·2 in. in diameter including the wing, orbicular, tapering down to the stalk, one- or two-seeded, the central portion, containing the seeds, hard and bony : about 550 to 600 pods weigh 1 lb. Seeds (Fig. 114, *b*) 0·4–0·5 in. long, dolabriform, flattened, reddish brown, smooth, shiny, testa fairly thin and brittle. The tree seeds abundantly almost every year. The immature pods are destroyed in large quantities by parakeets during the cold weather months. Most of the ripe pods remain on the tree during the months of March, April, and May.

Tests carried out in the Andamans have shown that the seed retains its fertility unimpaired for at least two years if stored in a dry place. So far as experience goes, however, the percentage of fertility is not as a rule high. Tests carried out at Dehra Dun and in the Andamans in 1911 showed a fertility of 50 and 60 per cent. respectively : in the latter case the seed had been stored for a year. Seed sown in plantations in different parts of Burma showed percentages of success amounting to 16, 20, and 23, while in the Andamans in 1911, even when five pods were sown at each stake, the percentage of success amounted to only 68 : in plantations, however, the percentage of success would naturally be lower than the percentage of fertility as ascertained by careful tests, though for practical purposes it is probably of more value.

GERMINATION (Fig. 114, *c–h*). Epigeous, resembling that of other species of *Pterocarpus*. Two fertile seeds are rarely contained in one pod, so that as a rule only one seedling emerges. The radicle issues from the side of the pod opposite the stalk, and bends downwards into the ground. The pod either is left on or in the ground, the cotyledons extricating themselves by the arching of the hypocotyl, or is carried up above ground, falling with the expansion of the cotyledons. The testa remains inside the pod.

THE SEEDLING (Fig. 114). Description of plants grown under natural conditions.

Roots : primary root moderately long, terete, tapering, wiry to woody : lateral roots numerous, fibrous, distributed down main root : nodules present. *Hypocotyl* distinct from root, 1·2–2 in. long, compressed, fusiform or tapering upwards, green, minutely pubescent. *Cotyledons* sub-sessile, foliaceous, somewhat fleshy, 0·8–1·2 in. by 0·3–0·4 in., unequally ovate oblong, apex rounded, base semi-truncate, entire, green, glabrous ; glands present on the hypocotyl between the cotyledons. *Stem* erect, terete, tomentose : internodes in first season 0·2–0·8 in. long. *Leaves* alternate, petiolate, first few simple, followed usually by a few trifoliate leaves, then by 4-foliate leaves, after which the number of leaflets increases ; sometimes no compound leaves are formed until the second season. Stipules 0·1 in. long or less, linear falcate, pubescent.

Simple leaves with petiole 0·2–0·5 in. long, channelled above, pubescent; lamina 0·6–2·5 in. by 0·5–1·5 in., ovate or cordate acuminate, slightly mucronate, entire, glabrescent above, pubescent beneath; early leaves small, successive leaves increasing in size.

In the Andamans the germination of the seed takes place during the rainy season, for the most part up to the end of July, and under favourable conditions the development of the seedling is rapid. In *taungya* plantations, where the forest growth is cleared and burnt prior to the sowing of the seed and the seedlings are regularly weeded, a height of as much as 5 ft. or even more may be attained by the end of the first season, whereas under natural conditions where insufficient light is admitted and weeding is not carried out a height of not more than a few inches may be attained in the same time, though in openings where there is abundance of light natural seedlings may, like those in plantations, attain a height of 5 ft. or more. Suppression by dense low cover is fatal to the seedlings: and although they will persist under the moderate shade of high tree cover, abundant light is necessary for their best development. If regular weeding be carried out a height of several feet is attained by the end of the second season: in a *taungya* plantation of 1911, on padauk-bearing land in the South Andaman, a height of 8 to 10 ft. was recorded one year from date of sowing, that is, in the middle of the second season.

Experiments carried out at Dehra Dun have shown that in the case of pods lying above ground the radicle of the germinating seed, as in the case of other species of *Pterocarpus*, is very liable to dry up if exposed to a hot sun; it suffers also from the attacks of insects and birds. If the pods are buried there is much less mortality during the germinating stages. In the Andamans the seedlings suffer much from cattle grazing in areas where cattle are admitted: in plantations in Burma young plants have been found to be very subject to the attacks of deer, which, however, are not found wild in the Andamans. Crickets have also been the cause of much mortality among seedlings in the Burma plantations.

In its natural home the young plant suffers much from the attacks of defoliators during the first few years of its life, the leaves often being entirely stripped off. Perhaps the worst enemy of the young sapling, however, is the padauk weevil, which causes immense damage, particularly in plantations. This insect is prevalent during the rainy season, its mode of attack being to ring all the young tender shoots as soon as they are produced; these shoots die off and are replaced by new ones, which are in turn ringed and killed off until the young plant assumes a bush-like form. The more vigorous plants eventually survive and produce leading shoots, but the weakly ones succumb. After the first few years the saplings which survive are less subject to this form of damage, and eventually escape it altogether. It has been noticed that young natural plants growing close together are less subject to the attacks of the padauk weevil than more isolated plants.

Frost is unknown in the natural habitat of the tree, and, as might be supposed, the seedlings are extremely frost-tender if grown in localities subject to frost. Seedlings raised at Dehra Dun invariably died back during the winter, and never recovered.

Silvicultural characters. Although seedlings will stand a fair amount of shade from high cover, the tree is a light-demander, and the more overhead light it receives the better is its development.

The padauk grows best on well-drained low undulating ground, where it attains large dimensions; on flat ground, where the drainage is not so good, although it may reach a considerable size it tends to form large buttresses and is often unsound. Although the trees are not so numerous in the semi-evergreen as in the deciduous type of forest they attain larger dimensions in the former; in the latter type, although the trees are numerous they are more stunted.

The tree coppices well, and Mr. Osmaston remarks that this power is retained to a great age, since quite old trees on being felled frequently send up strong shoots.

NATURAL REPRODUCTION. The unsatisfactory state of the natural reproduction of padauk in the Andamans has been the subject of frequent comment on the part of officers who have inspected the forests of those islands, and the unanimous opinion recorded is that natural reproduction throughout the great bulk of the forests is almost entirely absent.

Under natural conditions germination may take place as early as April, and it continues for some time into the rainy season, when numerous seedlings may be found; these, however, disappear before the following year owing to suppression by the dense undergrowth. Only in the drier and poorer types of forest, where the undergrowth is scanty, do seedlings appear to be able to survive to some extent. In the North Andaman, where the type of forest is somewhat drier than elsewhere, Mr. Todd [1] remarks that, except where there is a dense undergrowth, padauk saplings may be found in fair quantity, the overhead canopy being open; he notes that the seedlings appear capable of standing a considerable amount of shade as long as the canopy causing the shade is at some height from the ground, and instances the case of padauk saplings growing vigorously in bamboo forest where there is usually little or no undergrowth, in spite of the heavy canopy 20–30 ft. above them.

Omitting those parts of the North Andaman where the undergrowth is scanty or absent, however, it may be said that the natural reproduction of padauk is under ordinary conditions absent for all practical purposes. It was at one time thought that this failure was due to a large extent to infertility of seed or to its destruction by parrots, but this theory has been exploded for some time, since there is often no lack of young seedlings in the neighbourhood of seed-bearers, though they cannot survive many months owing to suppression, while the parrots do not consume excessive quantities of seed. On the other hand, natural seedlings appear freely where sufficient light is admitted to the soil, and plentiful natural reproduction has repeatedly been observed in areas where heavy fellings have taken place, on land cleared for plantations, along dragging paths, along the tramway-line clearing, and in similar openings in the canopy. It has been found by experience, however, that even in places where seedlings appear in quantity owing to the admission of light they are doomed to extinction unless kept free by means of cleanings from the masses of creepers and soft woods which grow up with them and would otherwise quickly suppress them.

---

[1] Ind. Forester, xxxii (1906), p. 583.

The amount of light required and the nature of the operations necessary to ensure the establishment of natural reproduction have been the subject of some discussion in the past, it being held on the one hand that so long as low cover is removed it is advisable not to make too drastic an opening in the upper canopy owing to the danger of stimulating weeds and climbers, and, on the other hand, that the padauk seedlings and saplings cannot have too much light, and that the admission of sun to the ground has a most beneficial effect. Recent experiments, involving the opening of the canopy and the removal of cover in different degrees of intensity, have indicated that the latter view is the more correct one, and that the more light admitted the better will be the development of the young crop.

To sum up, it has now been sufficiently well proved that good natural reproduction can be secured wherever seed-bearers are present by opening out the overwood heavily, removing the underwood completely, and carrying out thorough cleanings as often as is necessary until the young crop of padauk is established. It is believed that in the majority of cases annual cleanings for three or four years, with subsequent cleanings at less frequent intervals, will suffice.

Mr. Cavendish has observed that in areas which have been worked over the best natural reproduction occurs in openings caused by fellings made at the time the padauk seed is ripe on the tree, that is, from March to May, and that very little reproduction takes place when fellings are made at other times of the year: he therefore advocates felling only in these three months.[1]

ARTIFICIAL REPRODUCTION. The first regular plantations of padauk in the Andamans were made between the years 1883 and 1889. No further plantations were made until 1903, since when fairly extensive areas have been planted up from time to time. Where these plantations have been formed on typical padauk-bearing land and have been properly tended they have proved successful, but in some cases they have been formed on the non-calcareous micaceous sandstones of the Port Blair series on ground naturally occupied by evergreen forest, and here the growth has not been good.

In the case of regular plantations the system commonly adopted has been to clear and burn the natural forest, sow the pods at regularly spaced intervals, and carry out subsequent weedings and cleanings as often as necessary. Experience has shown that an essential condition for success is the complete and early burning of the natural forest in order, first, to diminish the heavy growth of weeds and climbers which spring up after the burning, and which is intensified if the burning is incomplete; and second, to allow of the padauk seed being sown before the early showers preceding the monsoon in order to induce early germination. For this purpose it is advisable to clear the forest early enough to allow of thorough burning before the end of March and the sowing of the seed in April before the early showers.

Various spacings have been tried, but a spacing of 6 ft. by 6 ft. has been found more satisfactory than spacings of 12 ft. by 3 ft. or 10 ft. by 4 ft., as a heavy growth of grass is apt to spring up between widely spaced lines. Usually two pods have been sown at each stake, but in order to ensure more complete success the number was subsequently increased to five, about 20 lb.

---

[1] Forest Administration Report for the Andamans, 1916–17.

of pods being required for one acre. Temporary nurseries are formed in the plantations for the purpose of supplying failures by transplants during the first rains. The question of spacing has not yet been satisfactorily settled, for although with a spacing of 6 ft. by 6 ft. the crowns of the saplings commence to form a complete canopy in five to seven years, this spacing has been found to be too wide to prevent low branching and to produce clean straight boles. It has recently been suggested that broadcast sowing would give better results, and experiments carried out so far indicate that this method may prove to be a better one than that of regular spacing, though further experience is desirable in this direction.

After the formation of the plantation its success depends almost entirely on efficient tending. During the first two years regular weedings and cleanings are necessary as a rule about once in two months from April to December, in order to free the padauk from the heavy growth of weeds and climbers which springs up; in the third and fourth years cleanings at longer intervals are necessary. As a rule from the fifth year onwards little is required except occasional thinning and climber cutting. The thinnings should be light and fairly frequent, and should be confined to dominant stems, exposed edges of plantations being left unthinned in order to provide wind-belts. In the early weedings and cleanings care is necessary not to root up the seedlings of soft-wooded species, but merely to cut them back or lop them sufficiently to free the heads of the young padauk, for if the latter are completely freed they tend to branch low down and also to show poor development in the presence of a rank growth of grass which usually springs up when the soil is exposed. The plantation clearings in the Andamans are often covered at an early stage with a prolific growth of natural seedlings of *Trema amboinensis* (closely allied to *T. orientalis* and perhaps not specifically distinct), which perform a useful function in sheltering the ground and drawing up the young padauk; these require cutting and lopping where necessary, but should not be uprooted.

For some years field crops were raised along with the padauk during the first year of the plantation, in order to keep down the weed-growth and to recoup the cost of formation. The only satisfactory crop was found to be the Burma hill paddy, which was sown early in June, a month or more after the padauk: it was found advisable to sow the paddy between the lines of padauk, leaving clear strips along the lines sufficiently wide to prevent the suppression of the seedlings. These plantations with the aid of field crops have not proved to be as successful as was anticipated, for in order to obtain good crops of paddy it was found necessary to clear the weed-growth more drastically than was good for the padauk; latterly therefore the system of raising field crops in the plantations has been abandoned.

The question of forming mixed plantations of padauk and other species of trees, with the view of imitating natural conditions, has been considered. Some of the earlier plantations in the Andamans consisted of an evenly spaced mixture of teak and padauk, but such a mixture has proved unsuitable, since the teak grows more rapidly than the padauk and soon outstrips and suppresses it. A mixture of padauk and pyinma (*Lagerstroemia hypoleuca*) was tried in 1904, and in its earlier stages the plantation showed great promise; later, however, it was found necessary to cut out the pyinma, as it was commencing to suppress the padauk. The question has recently been raised as to whether it would not be preferable to employ the available labour in the Andamans in forming plantations of teak rather than of padauk. The former is not indigenous in the islands, but has been introduced and grows remarkably well: there can be no doubt that with its more rapid growth and greater volume production as compared with the padauk it would prove a more remunerative species.

Apart from regular plantations, cultural operations have been tried from time to time in the Andamans. Of these one of the most promising was carried out in 1912 over 40 acres in a forest worked many years previously, in which only hollow trees remained. The undergrowth was cleared, and where the seedlings were numerous under the hollow padauk trees they were transplanted to other parts of the area. This experiment proved very successful where the cover was subsequently kept down.

Attempts to form plantations of Andaman padauk have been made in various parts of Burma. It has been proved that plants can be raised with tolerable success in suitable localities, but on the whole the experiments have resulted in failure. It was found necessary to raise the plants in nurseries and transplant them during the rains. The young seedlings were found to be very subject to the attacks of crickets, while in the plantations deer did much damage by browsing and by nibbling the bark. Seedlings have recently been raised with success in Coorg, but it is too early to say if the introduction of the padauk into that province will meet with success.

In the Andamans plantations the chief danger to be feared is the padauk weevil, which has already been referred to. Fortunately the damage done by this insect, though serious while it lasts, appears to be confined to young plantations, and the trees eventually outgrow the injury.

SILVICULTURAL TREATMENT. The padauk forests of the Andamans have hitherto been worked under selection fellings. This method of working is the only one at present possible where the area to be dealt with is so large and labour is limited. At the same time it will be realized from what has been said above under 'natural reproduction' that the forests cannot be successfully regenerated by this method of treatment, and the only course open seems to be to set aside a suitable area to be regenerated during a period of years, with the idea of regenerating further areas in subsequent periods. The regenerative operations would consist of opening the canopy, clearing the undergrowth where seed-bearers are present, and carrying out repeated cleanings and subsequent thinnings in the regenerated crop; where seed-bearers are insufficient or natural reproduction fails, artificial methods of reproduction would be necessary. The most suitable method of opening the canopy to induce natural reproduction has not yet been determined by experience.

RATE OF GROWTH. The age of the padauk cannot be determined from annual rings. The rate of growth of natural padauk trees was calculated by Mr. Todd[1] in 1906 by measuring fifty trees on Chatham Island, in Port Cornwallis. This island was cleared of jungle in 1792 in order to establish a settlement, but was abandoned in 1796; thus the fifty trees measured must have been not more than 110 years old. The trees averaged 6 ft. 1·4 in. in girth, which gives a mean annual girth increment of 0·67 in. for an age of 110 years. At this rate an average tree might be expected to reach a girth of 7 ft. in 125 years; actually, however, the age of existing natural padauk trees 7 ft. in girth is probably higher, as the trees measured must have grown up under exceptionally favourable conditions. Measurements of 63 trees in a sample plot on Chatham Island, extending over three years, gave a mean annual girth increment for the period of 0·60 in.

---

[1] Draft Working Plan for the Forests of the North Andaman, 1906.

The rate of growth in plantations is considerably faster. The following figures represent the mean girth and height (excluding suppressed trees) obtained from a series of measurements made in plantations of different ages in the Andamans:

Pterocarpus dalbergioides: rate of growth in plantations, Andamans.

Age.	Mean girth.		Mean height.
years.	ft.	in.	ft.
2	0	3	6
4	0	5	13
6	0	7½	20
8	0	10	27
10	1	0	34
15	1	5½	46
20	1	11	55
25	2	4	63
30	2	9	70

Some of the plantations were formed on land not typically padauk-bearing, and some remained insufficiently thinned for a time, so that on carefully selected land, if the plantations are regularly thinned, a more rapid rate of growth in girth might be attained.

4. **Pterocarpus macrocarpus,** Kurz. Burma padauk (as regards the correct pronunciation of this word, see under *P. dalbergioides*, p. 277). Vern. *Padauk*, Burm.

This is the true padauk tree, the other trees known by this name (*P. dalbergioides*, Roxb., and *P. indicus*, Willd.) having been designated padauk owing to their resemblance to the indigenous tree of Burma.

A large deciduous tree. Bark grey, exfoliating in irregular scales, exuding when blazed a bright red astringent gum resin similar in appearance to the kino of *P. Marsupium*. Leaves 6–9 in. long with seven to nine coriaceous leaflets.

Exceptionally the tree grows to a height of 90–100 ft. and a girth of 12 ft., but ordinarily it attains a height of 50–70 ft. with a clear bole of 20 to 40 ft. and a girth of 4½ to 6 or 7 ft. Mr. A. Rodger records a tree 12 ft. 3 in. in girth in the Paungadaw reserve, Ruby Mines division, Upper Burma. Large trees are often buttressed at the base and are nearly always hollow in the centre.

The padauk furnishes one of the most important timbers of Burma. The sapwood is light yellowish brown, small, the heartwood bright yellowish red to brick red, sometimes streaked with brown, hard, very strong and durable. In point of colour and decorative value the wood of the Burma padauk cannot compare with that of the Andaman padauk (*P. dalbergioides*), but for purposes where great strength and durability and good seasoning qualities are required the former is one of the best of timbers. Its chief uses are for ordnance work, for which it is put to more uses than any other timber, wheel-work, frames and shafts of carriages, and agricultural implements. In Burma there is a large local trade in *padaungs*, or pieces usually 2 to 3 ft. long by 2 to 3 ft. in girth, used for the manufacture of cart-wheel naves. The stems yielding these pieces are commonly 3½ to 4½ ft. in girth at breast height.

DISTRIBUTION AND HABITAT. The padauk is found in suitable localities throughout the greater part of Burma from the 24th parallel of latitude in the Bhamo, Ruby Mines, Katha, and Shwebo districts southward to the Amherst district, and to a limited extent in South Tenasserim. On the east it extends, so far as Burma is concerned, to the borders of Tenasserim on the Thaungyin river and occurs in at least one locality east of the Salween river in the Southern Shan States. The principal padauk tracts of the upper Irrawaddy drainage occur in the Shwebo, Ruby Mines, and Mandalay districts, ascending to 2,000 ft. ; the tree extends along the Shan hills to the east of the Kyauksè, Meiktila, and Yamethin districts, and thence southward along the hills east of the Sittang river. It is common in the northern portion of the Pegu Yoma in the Yamethin, Toungoo, Magwe, and Thayetmyo districts, extending south to the Prome district on the west and hardly entering the Pegu district on the east : it is unknown in Tharrawaddy and Hanthawaddy. It is found in the Chindwin drainage up to about the 23rd parallel of latitude, being common in the Taungdwin reserve of the Myittha forest division, and occurs on the eastern slopes of the Chin hills and the Arakan Yoma, extending as far south as the Thayetmyo district. It is found scattered in the lower Salween drainage and is locally common in the Thaungyin and Ataran drainages.

The Burma padauk is usually found on undulating to hilly country, occasionally ascending to 2,500 ft. elevation. It occurs on a variety of geological formations, including gneiss and other metamorphic rocks, limestone, soft sandstone, and shale ; it is sometimes found on laterite, but usually in stunted form. The tree requires good drainage, and is found most commonly on sandy loam ; where the proportion of sand is in excess, although trees of large dimensions are produced they are usually unsound in the centre.

The padauk tree of Burma is found most typically in the drier types of upper mixed forest, often mixed with teak, some of its other common companions being *Terminalia tomentosa*, *T. Chebula*, *Xylia dolabriformis*, *Homalium tomentosum*, *Vitex glabrata*, *Dalbergia cultrata*, *Phyllanthus Emblica*, *Acacia Catechu*, *Shorea obtusa*, *Pentacme suavis*, *Sterculia villosa*, *S. versicolor*, *S. ornata*, and others, together with various bamboos, of which the chief are *Dendrocalamus strictus*, *Thyrsostachys Oliveri*, *Oxytenanthera albociliata*, *Cephalostachyum pergracile*, *Bambusa polymorpha*, and *B. Tulda*. It is noteworthy that working plans enumerations show that some of the sample plots richest in padauk are characterized by an abundant growth of *Oxytenanthera albociliata*, a bamboo which thrives on sandy soils. In the ordinary type of upper mixed forest, as exemplified in the Pegu Yoma, the padauk ordinarily seeks the upper and drier portions of the hill slopes, a common mixture being teak and padauk on the upper slopes and teak and pyinkado (*Xylia*) on the lower and moister slopes. Towards the northern extremity of the Pegu Yoma padauk still persists, associated with such dry zone species as *Acacia Catechu* and *Tectona Hamiltoniana*, where the forest becomes too dry for teak. In the moister forests of this hill range the tree is absent. It extends in stunted form to the fringes of the dry zone of Upper Burma, for example on the dry outer hills bordering the Mandalay plain. The padauk sometimes occurs in *indaing* (dry dipterocarp) forest on laterite or sandy gravel, associated with *Dipterocarpus tuberculatus*, *Pentacme suavis*, *Shorea obtusa*, and other trees characteristic of this special type: here it does not attain large size. More commonly it avoids the usual *indaing* type and occurs in belts or patches of dry mixed bamboo forest of *Dendrocalamus strictus* between tracts of *indaing*, as in the southern part of the Ruby Mines district, where the tree is found on the broken ground along watercourses running through *indaing* forest, wherever the laterite soil gives way to richer soil. In this district, which produces some of the largest padauk in Burma, the tree reaches its best development in the drier parts of the bamboo forest, mainly of *Cephalostachyum pergracile* and *Thyrsostachys Oliveri*, on the lighter soils; here as a rule large growth denotes sandy soil and unsoundness in the timber, moderate growth denotes well-drained loamy soil and sound timber, and stunted growth denotes a heavy and unsuitable soil.

The padauk is not a gregarious tree, and as compared with teak, *Xylia*, and certain other trees it forms as a rule only a small proportion of the growing stock of the mixed forests in which it occurs. Working plans enumerations show that in the majority of cases the number of sound padauk trees 3 ft. in girth and over varies from 20 to 30 per 100 acres, and that padauk seldom forms more than $1\frac{1}{2}$ per cent. of the growing stock. Occasionally, however, padauk is abundant over comparatively small areas: thus in the Saing working circle of the Toungoo forest division a sample plot 47 acres in extent was found on enumeration to contain more than ten padauk trees 3 ft. in girth and over to the acre.

In the natural habitat of the padauk the absolute maximum shade temperature varies from 100° to 112° F., the absolute minimum from 40° to 52° F., and the normal rainfall from 35 to 180 in. or possibly more.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The tree is leafless for a time in the hot season, the new leaves appearing in April–May. The racemes of fragrant yellow flowers appear from March to May. The pods ripen in the cold season, and hang for some months on the trees, which are easily recognized when leafless by the flat round winged pods which are often present in large quantities; the pods fall for the most part during and towards the end of the hot season. The pods (Fig. 115, *a*) are 1·8–3 in. in diameter including the wing, finely pubescent, light greyish brown when ripe, the central portion hard and bony, containing usually one, more rarely two, seeds. About 650 to 900 pods weigh 1 lb. The seeds are dolabriform, reddish brown, 0·4–0·5 in. long, with a leathery testa. Although the pods are often produced in quantity the germinative power of the seed is comparatively low. This fact seems to require further inquiry: it has been suggested that the seed of pods which have hung long on the tree loses its germinative power, and that if fresh seed were collected a higher percentage of fertility would result, a point which requires verification. Various samples of seed collected in March were found to be of poor quality, and possibly seed should be collected earlier in the season.

GERMINATION (Fig. 115, *b*, *c*). Epigeous, resembling that of other species of *Pterocarpus*. One pod produces one or more rarely two seedlings. The radicle issues from the side of the pod opposite the stalk, bending downwards into the ground. The pod is either left on or in the ground, the cotyledons being extricated by the arching of the hypocotyl, or is carried up above ground, falling with the expansion of the cotyledons. The testa remains within the pod.

THE SEEDLING (Fig. 115).

Roots: primary root long, moderately thick, terete, tapering, wiry to woody: lateral roots moderate in number, fibrous, distributed down main root: nodules present. *Hypocotyl* distinct from root, 0·5–0·7 in. long, tapering downwards, glabrous. *Cotyledons* sub-sessile or shortly petiolate, foliaceous, somewhat fleshy, 0·8–1 in. by 0·3–0·4 in., unequally ovate oblong, apex rounded, base obliquely obtuse, entire, green, glabrous, venation arcuate reticulate. *Stem* erect, terete, zigzag at the nodes, green, with minute adpressed hairs. *Leaves* alternate, petiolate, first 6–8 simple, usually followed by one or more trifoliate leaves, then leaves with four or more leaflets. Stipules 0·15–0·4 in. long, linear acuminate, minutely hairy. Simple leaves with petiole 0·15–0·8 in. long, tomentose, petioles short in early leaves, longer in subsequent ones; lamina of first 1–3 leaves 0·25–0·6 in. long, that of succeeding leaves becoming larger, up to 3 in. by 2·3 in., broadly ovate to orbicular, obtuse or acute, mucronate, base rounded or cordate, entire, glabrescent with scattered hairs or with hairs on the principal veins. Compound leaves with leaflets alternate: petiolules up to 0·1 in. long; lamina broadly ovate, acuminate, base rounded or slightly cordate, entire, silky hairy before expanding, becoming glabrescent or glabrous; terminal leaflet larger than lateral ones, up to 3 in. by 2 in.

Under favourable conditions the growth of the seedling is fairly fast, nursery-raised seedlings in Burma showing a height of 8–12 in. in two months. The growth of natural seedlings is slower. A long taproot is developed early, and reaches a length of about 8–10 in. in two months. As regards the factors which influence the development and survival of the seedling, this species bears a close resemblance to other species of *Pterocarpus* in so far as the early development of the seedling is concerned. Thus as regards the germination stages, where pods lie on the surface of the ground the radicles are subject to the attacks of insects and birds, while if exposed to a hot sun they are very apt to dry up. Germination is found to be greatly favoured if the pods are covered with earth or protected from the sun; this has been corroborated by observations in the forest, to the effect that the early development of the seedlings is favoured where the pods lodge behind clods of earth or stones, or are sheltered by low cover. Loose soil greatly favours the growth of the seedling. In Burma young plants suffer much in nurseries from the attacks of crickets, and in plantations from damage by weevils, which kill off the young shoots by ringing the bark. Young plants also suffer much from browsing by deer. Frost does not occur in the natural habitat of the tree, and, as might be expected, the seedlings are very sensitive when grown in localities subject to frost; young plants have never survived the winter at Dehra Dun. Seedlings repeatedly burnt back have the power of sending up new shoots from a permanent thickened root-stock.

SILVICULTURAL CHARACTERS. The padauk tree is a light-demander, though possibly it is not so exacting in this respect as the teak. Although it grows best on deep well-drained porous soils it is not exacting as regards soil provided the drainage is good, since it is sometimes found in dry localities with poor shallow soil, though in such places it is stunted.

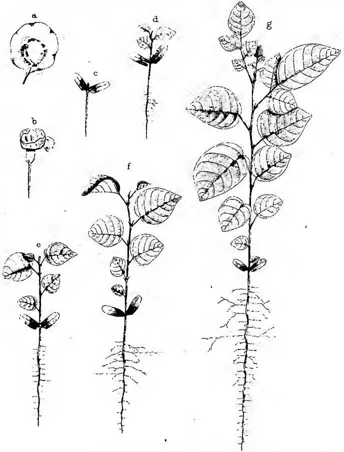

FIG. 115. *Pterocarpus macrocarpus*. Seedling × $\frac{3}{8}$.
a, fruit; *b*, *c*, germination stages; *d–g*, development of seedling during the first season.

NATURAL REPRODUCTION. As a rule natural reproduction is reported to be good only in rather dry open forests, and is scanty or absent in moist forests where the cover is denser. This appears to indicate that natural reproduction of this species, like that of the Andaman padauk, cannot establish itself under the suppression of low cover, and requires an abundance of light. Low cover, however, appears to favour germination and the early development of the seedling. Under natural conditions germination usually takes place during the early showers preceding the rainy season, and seedlings appear most commonly under the shelter of clods of earth, stones, &c. Mr. C. G. Rogers[1] records having observed in the Pyinmana forests one-year-old natural seedlings in an area where *Bambusa Tulda* had flowered recently. On the whole, natural reproduction in Burma is reported to be markedly deficient.

ARTIFICIAL REPRODUCTION. Attempts to form padauk plantations have been made in various parts of Burma, as a rule with little success, while the experimental dibbling of pods has proved a failure. Efforts to create plantations by transplanting nursery-raised plants, as well as by the *taungya* method of sowings in conjunction with field crops, have not been successful, partly owing to the poor germinating power of the seed and partly owing to damage by deer and by weevils. An experiment in sowing seed in small patches 6 ft. apart along a strip cleared of jungle proved equally unsuccessful. Mixtures of padauk with teak by the *taungya* system have also proved a failure, the teak rapidly outgrowing and suppressing the padauk. Most success has been attained by sowing the pods not later than April.

SILVICULTURAL TREATMENT. Hitherto padauk has been worked under selection fellings, the exploitable girth usually being fixed at 6 ft., and in the Ruby Mines forest division at 7 ft. and 7½ ft. in favourable localities. It will not be possible to devise a satisfactory method of silvicultural treatment until more is known regarding the measures necessary for securing successful natural or artificial reproduction. At the best this species can be regarded as only secondary to the teak wherever the latter will grow satisfactorily, since the teak grows faster, produces a larger out-turn, and is of greater value than the padauk.

RATE OF GROWTH. Detailed figures regarding the rate of growth of padauk are not yet available, and estimates based on ring-countings are unreliable owing to the indistinctness of the rings. Where padauk and teak have been tried together in plantations the latter has outgrown the former.

5. **Pterocarpus indicus,** Willd. Malay padauk. Vern. *Padauk*, Burm.

A semi-deciduous tree, attaining in Burma a height of 50 ft. or sometimes more, with a spreading crown of dark green foliage and drooping branches: the tree tends to form a short bole and to branch low down. Leaves 8–10 in. long with 5–9 leaflets. This is the padauk tree commonly planted along roadsides in Rangoon and other towns in Burma, and although commonly known as padauk in towns and stations it is not the true padauk tree of Burma. which is *P. macrocarpus*, Kurz, a tree typical of the forests. In Burma *P. indicus* is not important as a timber tree, but is largely planted for shade and ornament.

DISTRIBUTION AND HABITAT. This tree is believed to be indigenous in the Malay Peninsula and Archipelago, whence it has been introduced into Burma, where it has been largely planted in gardens and along roadsides and avenues in the damper parts of the country. It has also been planted to a small extent about Calcutta and Madras. More recently it has been introduced into Bombay, where it promises to do well. The tree appears to thrive best in a tropical climate with a rainfall of not less than 60 in. It requires a deep well-drained soil, and does not thrive on stiff clay.

---

[1] Inspection Note on Work of Burma Forest School, 1915.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The tree is leafless or nearly so towards the end of the cold season, but is in full foliage during the hot season, when shade is most required. The panicles of fragrant yellow flowers appear in two or three separate flushes early in the rainy season, about May to July, and the pods ripen in the cold season, about January–February. The pods (Fig. 116, *a*) are orbicular, 1–2 in. in diameter, including the wing, the central part bony, containing one, or more rarely two seeds. The seeds (Fig. 116, *b*) are 0·4–0·5 in. long, dolabriform, flattened, brown, smooth, shining, with a leathery testa, brittle when dry. The germinative power of the seed, as in the case of *P. macrocarpus*, is comparatively low.

GERMINATION (Fig. 116, *c–e*). Epigeous, resembling that of other species of *Pterocarpus*. As a rule one seedling emerges from each pod, but sometimes two seedlings are produced. The radicle issues from the side of the pod opposite the stalk and bends downwards into the ground. The pod is either left in or on the ground, the cotyledons extricating themselves by the arching of the hypocotyl, or is carried above ground, falling with the expansion of the cotyledons. The testa remains within the pod.

THE SEEDLING (Fig. 116).

Roots: primary root moderately long, terete, tapering, wiry to woody: lateral roots numerous, fibrous, distributed down main root: nodules present. *Hypocotyl* distinct from root, 1·2–1·8 in. long, slightly compressed with a ridge down one side, fusiform or tapering slightly upwards, yellow at first turning green, glabrous or very minutely pubescent. *Cotyledons* sub-sessile or with short petioles up to 0·04 in. long, foliaceous, somewhat fleshy, 0·9–1·2 in. by 0·3–0·5 in., unequally ovate oblong, apex rounded, base semi-truncate, entire, green, glabrous, venation arcuate reticulate; glands present on the hypocotyl between the cotyledons. *Stem* erect, terete, wiry, green, pubescent; internodes 0·2–0·8 in. long. *Leaves* alternate, petiolate, first few simple, followed by several trifoliate and later by 5-foliate leaves. Stipules 0·1 in. long, earlier ones linear acuminate, later ones sub-falcate. Simple leaves with petiole 0·2–0·5 in. long, terete, pubescent; lamina 0·6–1·9 in. by 0·3–1·2 in., cordate or broadly ovate, acute or acuminate, mucronate, glabrous above, sparsely pubescent beneath. Trifoliate leaves with rachis 0·7–1·5 in. long; leaflets alternate, with short petiolules 0·04 in. long, broadly ovate, acuminate, mucronate, base rounded or obtuse, entire, glabrous above, sparsely pubescent beneath; terminal leaflet 1–2·2 in. by 0·8–1·6 in., lateral leaflets 0·6–1·2 in. by 0·5–0·8 in.

As in the case of other species of *Pterocarpus*, it has been found that if the pods lie uncovered on the surface of the ground during germination the radicle is very subject to damage by insects and birds, while if exposed to the sun it is apt to dry up. Loose soil and protection from the sun favour the early development of the seedling. Frost is unknown in the natural habitat of the tree, and, as might be expected, the seedlings are very sensitive if grown in localities subject to frost: they have never survived the winter at Dehra Dun.

ARTIFICIAL REPRODUCTION. The tree is commonly propagated by large cuttings, which should be planted in prepared pits in rather sandy soil early in the rainy season, or, if watering can be carried out, about the month of February. Nursery-raised plants are ready for transplanting at the commencement of the second rains, when they are rather more than one year old: planting can be most successfully carried out by transferring the seedlings to bamboo baskets during the first rains and planting them out in the baskets during the second rains.

5. DALBERGIA, Linn. f.

This genus is an important one silviculturally and economically. There are between thirty and forty Indian species, several of them straggling or scandent shrubs. Some of the trees are of little or no economic value, possessing whitish woods without heartwood; the best known of these are *D. lanceolaria*, Linn., and *D. paniculata*, Roxb. Others are of great value owing to their dark-coloured ornamental heartwood. The two most important timber trees of the genus are *D. Sissoo*, Roxb., and *D. latifolia*, Roxb., which have been studied silviculturally in much greater detail than any of the others. Two others with ornamental woods, *D. cultrata*, Grah., and *D. Oliveri*, Gamble, have received preliminary study and are included below. *Dalbergia* pods are flat and indehiscent even during germination, with one or a few seeds, and those of several species are light and well adapted for dissemination by wind. Some at least of the species are known to produce root-suckers freely.

Species 1. *D. Sissoo*, Roxb.; 2. *D. latifolia*, Roxb.; 3. *D. sissoides*, Grah.; 4. *D. cultrata*. Grah.; 5. *D. Oliveri*, Gamble.

1. **Dalbergia Sissoo**, Roxb. Sissoo. Vern. *Shisham. sissu*, Hind.; *Táli*, Pb.

A large deciduous tree with a light crown; bark 0·4–0·6 in. thick, grey, longitudinally and somewhat reticulately furrowed. Leaves compound, with 3–5 alternate leaflets. In favourable localities it reaches considerable dimensions, sound trees up to 8 ft. in girth and nearly 100 ft. high being by no means uncommon in the Bengal Duars; in less favourable localities, as in the drier parts of the Punjab sub-Himalayan tract, it remains a comparatively small tree. The growth of the bole is as a rule somewhat crooked, and straight logs of any great length are difficult to obtain. The sissoo furnishes one of the most important timbers of India, and gives excellent fuel. The heartwood is brown with darker streaks, very hard, strong and durable: it is used for building, furniture, carts and carriages, wheel-work, gun-carriage wheels, carving, and a large number of other purposes. The sissoo is used in the tea-gardens of Dehra Dun as a shade tree and fertilizer for the tea-bushes.

Distribution and habitat. Throughout the sub-Himalayan tract from the Indus to Assam, and in the Himalayan valleys, usually up to 3,000 ft., but sometimes ascending to 5,000 ft. It descends the rivers for some distance into the plains. It is cultivated or self-sown in many parts of India. In its natural state the sissoo grows most typically on alluvial ground in the beds of rivers; this alluvial type of forest is described below. The tree is, however, by no means confined to alluvial ground, and springs up freely wherever the soil is exposed, as on landslips, on hill-sides, on new embankments, and such places; it springs up frequently along water-channels, as well as on grass-lands where the soil is exposed. It occurs in the Rawalpindi district in the

NATURAL RIVERAIN CROPS ON ALLUVIAL GRAVEL

Dalbergia Sissoo. Ramganga river, United Provinces

FIG. 117. Stage 1. In the foreground natural reproduction of sissoo up to 5 ft. in height springing up amongst grass, chiefly *Saccharum Munja* and *S. spontaneum*; older crop of sissoo in background.

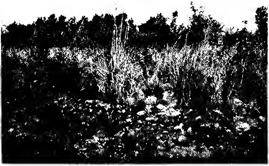

FIG. 118. Stage 2. Young crop about 10 ft. high appearing over and beginning to suppress grass, *Saccharum spontaneum* and a little *S. Munja*.

FIG. 119. *Dalbergia Sissoo*. Ramganga river, United Provinces. Stage 3. Dense young crop averaging 15 ft. in height, grass killed out below trees.

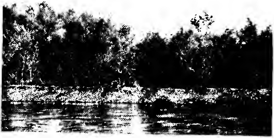

FIG. 120. Stage 4. Crop 20 ft. high on bank of river.

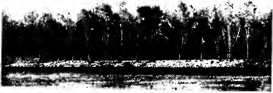

FIG. 121. Stage 5. Pole crop 40 ft. high.

form of a straggling bush at an altitude of 5,000 ft., clinging to crevices on the sides of sandstone cliffs and spreading by means of root-suckers. In the Kangra valley it may be seen on hilly ground in somewhat open crops associated with *Pinus longifolia*, *Acacia Catechu*, and various miscellaneous species, ascending to 4,000 ft. Detrital boulder fans, torrent-beds, and taluses along the base of the outer hills are often covered with dense crops of sissoo. The tree avoids stiff clay, preferring a porous soil of sand, pebbles, and boulders : trees growing on clay are invariably stunted.

In the natural habitat of the sissoo the absolute maximum shade temperature varies from 102° to 120° F., the absolute minimum from 25° to 42° F., and the normal rainfall from 30 to 180 in., though the tree is of small size where the rainfall is less than 40 in. The sissoo probably reaches its finest development on the riverain tracts of the Bengal Duars, where the absolute maximum and minimum shade temperatures are about 103° and 35° F. respectively, and the normal rainfall varies from 130 to 180 in.

The alluvial sissoo forests are a characteristic feature of the rivers and streams of the sub-Himalayan tract and the outer Himalayan valleys. Here the tree grows gregariously in the beds of the rivers on the new alluvial land thrown up in the shape of islands or low banks formed of deposits of sand, shingle, and boulders, the sissoo forming forests either pure or mixed with *Acacia Catechu*. As the streams alter their courses or add fresh deposits, these forests are gradually elevated, and as this process continues, successive terraces of even-aged crops of different ages may be observed at various heights above river-level. Sometimes the advent of the sissoo is preceded by or is simultaneous with that of *Tamarix dioica*, while almost invariably grasses appear along with or immediately before or after the sissoo. In the western sub-Himalayan tract one of the most characteristic grasses through which the sissoo makes its way is *Saccharum Munja*, Roxb.. the *moonj* grass, which sometimes occupies large stretches of rather dry sandy or shingly alluvium : other characteristic grasses associated with the early development of alluvial sissoo crops in this tract are *Saccharum spontaneum*, Linn. (the tufted sandy form), *Aristida cyanantha*, Steud. ex Trin., and *Triraphis madagascariensis*, Hook. f. When the sissoo crops come up with their characteristic density the grasses are gradually killed out, and frequently a dense undergrowth of *Adhatoda Vasica* appears. As the crop gets older and becomes thinned out by fire, felling, or other causes, miscellaneous species such as *Ehretia laevis*, *Holarrhena antidysenterica*, *Odina Wodier*, *Bombax malabaricum*, *Kydia calycina*, *Premna latifolia*, and others take the place of the sissoo, and a different type of forest comes into being. Often, however, this stage is never reached, for the rivers and streams frequently alter their courses and carry away every year considerable stretches of immature sissoo forest ; the wastage from this cause is at times considerable. Figs. 117 to 121 show the various stages in the development of riverain sissoo crops, and Fig. 123 shows a crop in process of destruction by erosion.

In the moist climate of the Duars the alluvial sissoo forests are characterized by the presence of a much more luxuriant growth of giant savannah grasses than is the case in north-western India. The chief species are *Saccharum arundinaceum*, Retz., *Erianthus elephantinus*, Hook. f., *Anthistiria gigantea*, Cav., and in moister places *Phragmites Karka*, Trin. Where fire and grazing are excluded these grasses form a dense mass 12 to 20 ft. or more in height, and when fire does gain admission, as is almost bound to happen from time to time, the damage done is enormous; pole crops may be entirely destroyed, and even large trees may be killed. The result is that by the time the crop reaches maturity it often consists of widely scattered trees, many of which are badly damaged by fire. In these forests there can be little doubt that the admission of grazing as soon as the young crop is out of reach of cattle would be of much benefit in keeping down the rank growth of grass and minimizing the damage by fire. The most common companions of the sissoo in these tracts are *Acacia Catechu*, *Albizzia procera*, and *Bombax malabaricum*.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The leaves begin to fall in November, turning brown prior to falling; the leaflets fall separately. In cold situations the trees may be leafless by the beginning of December, while in some places the leaves have not all fallen by the end of January. The leaf-shedding is often very regular over the whole forest, all the trees being leafless and the sissoo woods in the river-beds having a characteristic bare grey appearance, contrasting strongly with the dark green foliage of the sal forest which so often occupies the high ground above the rivers. The young leaves appear in the second half of January or in the first half of February, and by the middle or end of February, when the new foliage has burst forth, the woods with their mantle of delicate green have a strikingly beautiful appearance, which is often intensified in combination with the vivid scarlet of the *dhak* trees (*Butea frondosa*), which flower when the foliage of the sissoo is young and fresh. The young delicate shoots are a favourite food of monkeys.

The young flower-buds appear with the new leaves, and the yellowish flowers, in axillary panicles of short racemes, open in March or April. The young pods form very rapidly, and by the end of April they may be as much as 2 in. long, pale green, and hanging in masses all over the tree: by July they are full-sized, but remain unripe and yellowish green until November, when they commence to turn brown, ripening towards the end of that month and during December and early January. The pods (Fig. 122, *a*), when ripe, are 2–3·5 in. by 0·3–0·5 in., pale brown, flat, 1- to 3-seeded, and like all *Dalbergia* pods are indehiscent. About 6,000 to 7,000 pods weigh 1 lb. The seeds (Fig. 122, *c*) are 0·25–0·3 in. by 0·15–0·2 in., reniform, flat, light brown, with a delicate papery testa.

Numbers of pods are blown off the trees from the time they ripen onwards, and are carried to some distance by the winds which blow down the gorges and rivers of the sub-Himalayan tract in the winter. Many ripe pods, however, remain on the trees until April, some even till May. Parrots destroy quantities of the pods while still green and unripe, and also to some extent after they ripen; nevertheless, the crop is ordinarily so abundant that the trees are laden with masses of ripe pods from November onwards.

Records of seed-years have been kept for a long series of years in different parts of the United Provinces and Bengal; these show that poor seed-years are very rare, and when they do occur are possibly due to some abnormal factor, such as was the case in the severe drought of 1907–8 in Oudh. With such rare exceptions the sissoo produces an abundant crop of pods each year.

The trees produce fertile seed at an early age. Saplings two years old in a nursery bed at Dehra Dun flowered and produced a few pods, which were not tested; the pods produced the following year, that is, at an age of three years, were tested and the seed was found to be fertile. It has been recorded that seed from coppice-shoots eight years old in the Changa Manga irrigated plantation germinated indifferently; that obtained from coppice twelve years old in the same plantation germinated well, while seed from coppice nine years old in the Shahdera *sailaba* plantation also germinated well. More recently seed from coppice five years old in Changa Manga was found to germinate as well as that obtained from mature seedling trees.

The ripe pods can best be collected by men ascending the trees with bags or baskets and pulling the pods off in handfuls. The pods may also be beaten off the trees with sticks on to ground which has been previously swept. The seed, if stored in a dry place, retains its vitality to some extent for at least one year: seed from pods stored for one year was tested and found to have a fertility of 40 per cent.

GERMINATION (Fig. 122, *b*, and *d*–*i*). Epigeous. The radicle emerges from one end of the seed and curves downwards. The pod valves, which are brittle when dry, become soft when soaked by rain or river-water, and the radicle and young shoot have no difficulty in pushing their way through them, the testa being either carried up on the cotyledons, falling with their expansion, or left inside the pod. The hypocotyl arches in emerging from the pod, but soon straightens.

THE SEEDLING (Fig. 122).

Roots: primary root long, at first thin, afterwards thickening considerably, terete, tapering: lateral roots numerous, fibrous, distributed down main root: nodules present. *Hypocotyl* distinct from root, 0·8–1·3 in. long, terete, tapering slightly upwards, white turning green, pubescent. *Cotyledons*: petiole up to 0·05 in. long: lamina 0·4–0·5 in. by 0·25–0·3 in., foliaceous, somewhat fleshy, reniform with an angular projection on the basal half of the incurved side, apex rounded, base sagittate, entire, green, glabrous, obscurely 3-veined from the base. *Stem* erect, terete, thin, wiry, green, pubescent, zigzag at the nodes particularly in later stages; internodes 0·25–0·8 in. long. *Leaves* alternate, first leaf simple or trifoliate, subsequent leaves trifoliate, followed by 5-foliate, or occasionally one or two 4-foliate leaves. Stipules up to 0·1 in. long, sub-falcate, acuminate; stipels absent. Simple leaves with petiole up to 0·06 in. long; lamina 0·2–0·25 in. by 0·1–0·15 in., ovate, acute, mucronate, entire. Trifoliate leaves with rachis 0·2–0·5 in. long, slender, pubescent; stipels absent, petiolules up to 0·05 in. long; terminal leaflet 0·3–1 in. by 0·2–0·6 in., ovate elliptical or rhomboidal, apex acute or rounded, mucronate, entire, pubescent when young; lateral leaflets opposite, 0·2–0·5 in. by 0·15–0·4 in., ovate or elliptical, apex acute or rounded, mucronate, entire, pubescent when young. Subsequent 5-foliate leaves with leaflets similar but increasing in size, lateral leaflets alternate.

The factors influencing the development of seedlings and saplings are discussed below, and it will be seen that the rate of growth varies enormously according to the conditions under which the seedling grows. Where these conditions are at all favourable rapid growth takes place from the commencement, and continues in subsequent years. At Dehra Dun seedlings in a nursery bed well watered and weeded have attained in the first season a maximum height of as much as 4 ft. 9 in., while seedlings regularly weeded but not watered have attained a maximum height of 3 ft. 1 in. Such growth is well above the average, and under unfavourable conditions, for example where there is a dense growth of weeds, a height of only a few inches may be attained in the same time.

The seedling produces a vigorous taproot which may reach a length of 9 in. in one month and 3 to over 5 ft. by the end of the first year. In the first season the taproot is somewhat fragile, with fairly numerous fibrous lateral rootlets; both taproot and lateral roots are covered with nodules. Under natural conditions in riverain deposits of shingle and boulders the long taproot becomes curiously flattened at intervals by contact with the stones as it twists its way down between them. The taproot of the seedling has considerable vitality. In order to thin out a line of seedlings in sowings at Dehra Dun at the end of the first season, the taproots of the plants to be removed were cut through an inch or two below ground-level. Next year the taproots left underground sent up new shoots, and the process of cutting was renewed; fresh shoots were, however, again sent up, and finally the roots had to be dug out.

The season's growth ceases in October–November, new growth commencing in February. The old leaves of seedlings commence falling in November and December, and may continue falling till January: many seedlings are leafless during December and January, but in moist situations the leaves may be retained until January or February. Natural seedlings are not so regular in their leaf-shedding as the adult trees in the neighbourhood. The seedlings are decidedly frost-hardy, and though in severe frosts they are sometimes killed back, they have good power of recovery. Young seedlings are particularly sensitive to drought, and suffer much if there are intervals of dry hot weather during the first rainy season. The whitish mildew fungus *Phyllactinia corylea* attacks the leaves of young plants of different ages as well as those of older trees. It is prevalent towards the end of the year, not long before the leaves fall, and is therefore probably less noxious than it would otherwise be. The seedlings are browsed by cattle, goats, deer, and hares, the damage done being at times considerable. In grassy land rats gnaw through the taproots and may kill the plants.

Factors affecting development of seedlings and saplings. The factors affecting the development of sissoo plants during the first few years have been studied in considerable detail by means of a large number of experiments carried out at and near Dehra Dun. The chief factors influencing this development are: (1) abundance of light; (2) sufficient growing space; (3) porosity of soil; (4) freedom from weeds; (5) a plentiful supply of water. As regards light, experiments carried out under varying shade conditions showed that under shade which is fairly dense the seed germinates satisfactorily, but the seedlings die off before the first rainy season is well advanced. In full light the development is always better than under partial shade. The effect of growing space on the development of saplings is seen in the manner in which the more vigorous members of a young crop take the lead from the first season and suppress the remainder. Experiments in thinning line sowings resulted in a much more satisfactory development than in the case of lines left unthinned; it was found

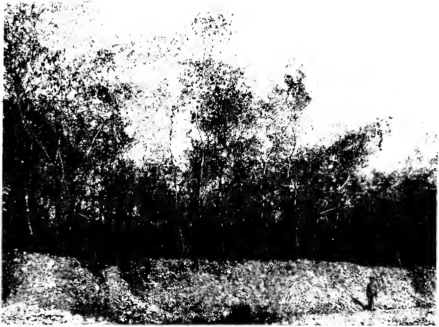

FIG. 123. *Dalbergia Sissoo*, pole crop, mean girth 10.2 in., mean height 30 ft., on elevated river-bank subject to erosion, Dehra Dun, United Provinces; trees infested with climber *Dregea volubilis*.

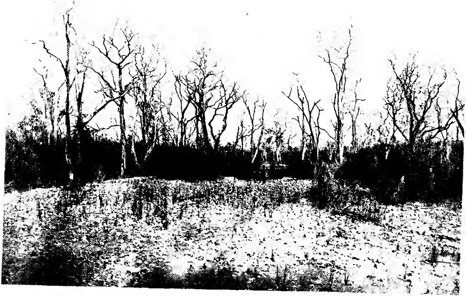

FIG. 124. Riverain forest of *Dalbergia Sissoo* and other species killed by excessive deposits of silt, Raidak river, Buxa, Bengal.

that in order to ensure the best results the thinning should start not later than the end of the first season, and should be repeated annually for a few years. Porosity of soil has a marked effect on development : on stiff clay the plants always remain stunted. The beneficial effects of soil-aeration resulting from periodic loosening of the surface soil combined with the eradication of weeds have been demonstrated in a marked degree in experiments at Dehra Dun, the results of which are given on the next page : these results refer to two separate sets of experiments : (A) broadcast sowings in Surajbagh garden ; and (B) line sowings in Kaunli garden. It was found that the effects were most marked in the first season, less so the next year, and least of all subsequently. Irrigation, as these experiments show, also has a decided effect on the growth of seedlings and saplings, as well as of trees, but in the young stages the effects of irrigation are largely discounted if weeding is not carried out : indeed weeding and loosening of the soil give much better results than irrigation without weeding, and in some cases the results attained by unirrigated sowings are not much inferior to those attained by irrigated sowings where weeding and loosening of the soil are carried out in either case.

Silvicultural characters. The sissoo is a strong light-demander ; in the dense crops which it often forms the more vigorous trees tend to suppress and kill out the weaker ones. It is decidedly frost-hardy : the leaves are sometimes affected by severe frost, but the tree is not seriously injured. In the abnormal frost of 1905 in northern India the trees suffered comparatively little damage, except that there were numerous cases of frost-crack in the plantations of the Lahore district. Seedlings are sensitive to drought, but in its natural state the tree is fairly hardy ; in the abnormal drought of 1907 and 1908 in Oudh the alluvial sissoo forests suffered comparatively little damage, though possibly they may have had the benefit of the river-water during the dry period. In irrigated plantations, as might be supposed, the trees die if the water-supply is cut off for any length of time.

Sissoo plants are readily browsed by cattle, goats, and camels ; where grazing is prevalent, seedlings and saplings are browsed down year after year, and coppice-shoots assume a dense bushy growth. The sissoo is not particularly fire-resistant, and the forests suffer greatly where there is much inflammable grass present.

It has already been noted that the sissoo will not tolerate stiff clay, and requires porous well-aerated ground for its proper development. In the sub-Himalayan tract sissoo forests, situated as they are in the neighbourhood of rivers, are occasionally killed by the accumulation of fresh deposits when the rivers change their courses (see Fig. 124) : these deposits no doubt deprive the roots of air and possibly prevent the action of bacterial agencies, thus causing death. Considerable mortality is caused annually by the mechanical action of rivers in eroding the banks and uprooting and sweeping away the sissoo trees, often before they attain marketable size.

Of fungoid pests the mildew fungus *Phyllactinia corylea* has already been mentioned as attacking the leaves of seedlings and saplings as well as of older trees ; it has not yet been noticed to cause any serious injury. A much more dangerous fungus is *Fomes lucidus* (Leys), Fr., which is the cause of much

Dalbergia Sissoo: results of experimental sowings, Dehra Dun.

A. Broadcast sowings in Surajbagh garden.

Five plots, each cleared of weeds, dug up and levelled: seed sown in March.

Plot No.	Treatment.		Maximum height-growth.			Condition.
			End of 1st year.	End of 2nd year.	End of 3rd year.	
1	Thoroughly irrigated, weeded, and soil loosened periodically		4 ft. 9 in.	13 ft. (Girth at 1 ft. from ground 6·4 in.)	19 ft. 7 in. (Girth at 1 ft. from ground 1 ft. 3·5 in.)	Vigorous.
2	Less freely irrigated	Weeded and soil loosened periodically	3 ft. 2 in.	9 ft. 7 in.	14 ft. 10 in.	A vigorous crop.
3		Not weeded	10 in.	1 ft. 9 in.	5 ft. 6 in.	Development impeded by growth of weeds and grass; plants much less vigorous than in plot 2. The larger plants only where weeds scanty.
4	Not irrigated	Weeded and soil loosened periodically	3 ft. 1 in.	6 ft. 3 in.	9 ft. 10 in.	A dense vigorous crop, in need of thinning.
5		Not weeded	9 in.	1 ft. 8 in.	4 ft. 8 in.	Development impeded by growth of weeds and grass; plants much less vigorous than in plot 4. The larger plants only where weeds scanty.

B. Line sowings in Kaunli garden.

Four lines, cleared of weeds, hoed up, and levelled: seed sown in May. In the irrigated lines seed sown along base of ridge thrown up along the side of irrigation channel.

Plot No.	Treatment.		Dimensions.			Condition.
			End of 1st year.	End of 2nd year.	End of 3rd year.	
1	Irrigated	Weeded and soil loosened periodically	Maximum height 3 ft. 9 in.	Height 1 ft. 2 in. to 12 ft. 6 in.	Average height 6 ft. 6 in. Maximum height 16 ft. 11 in. Maximum girth at 4½ ft. = 7 in.	Vigorous; line well filled.
2		Not weeded	Maximum height 8 in.	Height 10 in. to 5 ft. 11 in.	Height 3 ft. 8 in. to 13 ft. 3 in.	Large plant at end of line free of weeds. Plants otherwise irregularly scattered with poor development.
3	Not irrigated	Weeded and soil loosened periodically	Maximum height 1 ft. 10 in.	Height 1 ft. 4 in. to 9 ft. 3 in.	Maximum height 13 ft. 10 in. Maximum girth at 4½ ft. = 4 in.	Vigorous: line well filled.
4		Not weeded	All killed except a few weakly seedlings	One surviving, height 9½ in.	None surviving.	

28397

mortality among sissoo trees in plantations and elsewhere ; it is particularly prevalent in the Changa Manga plantation in the Punjab, where it has spread rapidly within recent years and killed out large numbers of trees of all sizes as well as coppice-shoots and root-suckers. The same fungus is very prevalent in tea-gardens near Dehra Dun, and is probably the cause of mysterious deaths noticed among sissoo trees in various other localities. The life-history of this fungus, in its relation to the sissoo, has not yet been studied in detail, nor have successful preventive or remedial measures for dealing with it yet been devised ; it is tolerably certain, however, that it is capable of spreading below ground, since trees showing progressive stages of attack are frequently found in rows. In Changa Manga affected trees are cut out as far as possible, and the large bracket-like sporophores which appear round the bases of the trees are removed. A preventive measure indicated by the tendency of the fungus to spread underground would be to grow the sissoo trees in mixture with other species and not in too close proximity to each other. This fungus, which is widely distributed throughout the world, is usually considered saprophytic, but in addition to its undoubtedly parasitic form on the sissoo it has been found with strong presumptive evidence of parasitism on other species of trees in India, for example *Acacia arabica*, *Cedrela Toona*, *Areca Catechu*, and *Casuarina equisetifolia*, as well as on *Cassia siamea* in Java ;[1] it occurs, so far as is known in saprophytic form, on *Morus alba*. So serious has this fungus become in Changa Manga that experiments are on foot to ascertain what other species of useful trees are able to thrive there, since it is realized that it may be necessary largely to supplement the sissoo with other species.

Among phanerogamous parasites, *Loranthus longiflorus* is very prevalent on the sissoo, every tree being infected in some localities ; badly attacked trees succumb, the parasite then dying for want of sustenance. Alluvial sissoo forests are sometimes badly infested with the climber *Dregea volubilis*, which twines round the stems and over the tops of the trees, pressing down on the crowns and causing the trees to become stunted and badly shaped (see Fig. 123) ; the damage starts at an early stage in the life of the crop. Another fairly common climber in these forests in *Cryptolepis Buchanani* : though somewhat harmful, it is not so injurious as *Dregea volubilis*. Various climbers characteristic of other types of forest at times infest the sissoo forests, *Acacia pennata* being among the most noxious. Wind is at times a source of danger, uprooting the trees, particularly standards in recently felled coupes. This form of damage is most prevalent in irrigated plantations, where a superficial root-system is induced and the soil is kept in a soft condition by the water. Trees attacked by fungus at the base are also apt to be thrown by wind.

The roots of the sissoo are dimorphous, comprising nutrition roots without buds, penetrating downwards into the ground, and long horizontal roots with buds, from which suckers are produced. The seedling produces a long taproot at an early age : this thickens considerably during the sapling stage, becoming much gnarled and twisted by contact with boulders. In the meantime lateral roots are thrown out ; the original taproot often dies off in part and forms nothing more than a short thick gnarled mass in which boulders and pebbles are often embedded: this taproot is sometimes thicker than the bole itself, and may consist of several branches with numerous subsidiary fibrous nutrition roots. The lateral roots may attain considerable length and thickness; a tree 3 ft. 8 in. in girth in the Siwaliks was found to have lateral roots up to 30 ft. in length. The lateral roots spread at a depth of a few inches to about 2 ft. below ground surface, frequently sending up root-suckers, more especially where the roots have become exposed. The felling of the trees, particularly if carried out at or below ground-level, often results in a plentiful crop of suckers, the production of which may be stimulated by exposing the roots at intervals. In the Changa Manga plantation, however, this form o reproduction has proved far less successful than that obtained from stool-shoots.

---

[1] E. J. Butler in Ind. Forester, xxxv (1909), p. 514.

The sissoo coppices vigorously, often sending up masses of shoots, some from the cambium round the edge of the cut surface and some from the side of the stool. It is not certain up to what age or size the tree will coppice successfully; this probably depends on the vigour of individual stools and on other conditions. In Changa Manga trees are known to coppice well up to an age of at least twenty years. It has been noticed that the stumps of some trees cut out in thinnings in a plantation thirty years old in the Gorakhpur district, United Provinces, produced numerous coppice-shoots, though many failed to produce them; this is, however, hardly a fair test, since many of the trees removed would naturally have been less vigorous members of the crop, while the stumps in a thinned crop are not exposed to the favourable light conditions obtaining in a coppice coupe. Observations extending over some years in sample plots in the Changa Manga plantation have shown that the growth of coppice-shoots from untrimmed stools is in no way inferior to that obtained from trimmed stools, and the practice of trimming stools in that plantation has therefore been given up; in either case it was found that the stools rotted and the shoots produced independent root-systems. Some statistics of the rate of growth and out-turn of coppice are given below.

NATURAL REPRODUCTION. The light flat pods are disseminated in non-riverain tracts by wind and in riverain tracts either by wind or by water. It is sometimes stated that the seed has a hard testa which prevents its germination without prolonged soaking, and that this accounts for its usual occurrence in river-beds, where it receives long immersion in water before germinating. This is not correct, for the seed has an extremely delicate papery testa and not a hard one, and the pod valves when moistened quickly become soft enough to permit the germinating seedling to break through them without difficulty. The bulk of the pods reach the ground from the beginning of December till the end of April, and lie until they become sufficiently soaked to cause germination; this happens normally when the monsoon rains commence in June and July. If continuous heavy rain or river floods occur earlier in the season the seeds may occasionally be found germinating not long after the pods fall, but unless the seedlings receive sufficient water to keep them alive during the dry weather preceding the monsoon, which is seldom the case, they invariably die of drought. It may be said as a general rule that germination commences at the beginning of the monsoon as soon as the pods have been sufficiently soaked by rain. That the river floods assist in stimulating germination is no doubt true, but my own observations lead me to the conclusion that rain is a more important factor, for numerous germinating seedlings will be found early in the rains in riverain tracts in places well above the reach of floods; few if any of these, however, survive under trees or in the presence of weed-growth or heavy grass such as ordinarily springs up on the older and higher land. In the subsequent establishment of the young crop in riverain tracts the percolation of river-water is undoubtedly of great importance. The factors which favour the development of seedlings and saplings have already been alluded to; the open alluvial sandy and shingly river deposits of the sub-Himalayan tract present extremely favourable conditions for this development, namely full light, a highly porous soil, freedom from weeds, and as a rule sufficient moisture in the soil to tide over the dry season. On the new river-deposits the young plants are very commonly found making their way through grass, but the grasses on these sandy and shingly formations are usually in somewhat widely separated clumps (e. g. *Aristida cyanantha*, *Saccharum Munja*, and *S. spontaneum*): there is abundance of room for the seedlings to make their way, the grasses performing a useful function in affording side protection against the sun. The long taproot of the seedling is of great importance: not only does it secure the young plant from being washed away, but by the time the floods subside and the river-bed dries up on the surface it has established itself in the moister layers beneath, where in many cases the water from the river reaches it by percolation.

In non-riverain tracts the sissoo regenerates on newly exposed ground where weed-growth is scanty or absent, provided there is abundance of light. Thus crops of seedlings may be seen appearing on new embankments, landslips, heaps of stones, and such places, and in grassy tracts in places where the soil has been exposed by pigs grubbing up the soil. On abandoned cultivation the sissoo sometimes springs up in quantity if it succeeds in outgrowing weeds. Along the sides of water-channels saplings frequently appear, the water stimulating their growth sufficiently to enable them to overtop the weeds before they are suppressed. Experiments at Dehra Dun have shown that drought is a fruitful cause of mortality among natural seedlings, particularly if the pods lie on the surface of the ground without becoming covered, in which case large numbers of seedlings die off during germination. Another common cause of mortality in damp situations under shade is the rotting of seedlings during the first rainy season; apart from the effect of the shade, this is undoubtedly a common cause of mortality where seedlings appear under cover of trees or undergrowth. In short grass germination takes place freely and the mortality is not so great, but the subsequent development of the seedlings is slower than on exposed ground. Dense weed-growth entirely prevents the establishment of regeneration. A remarkable instance of this was observed near the Sankos river in Goalpara, Assam. Sissoo saplings were found to be numerous on the unprotected side of a straight fire-line and practically absent on the protected side: both sides of the line were open to grazing. The explanation of this somewhat anomalous result was that owing to the presence of much grass on the unprotected side the damage by grazing was less than it would otherwise have been, while owing to the effect of grazing in keeping the grass short. damage by fire was slight: on the fire-protected side, however, a comparatively heavy undergrowth was induced which effectually prevented the regeneration of the sissoo.

In spite of this somewhat exceptional example, fire and grazing are ordinarily most inimical to the establishment of natural reproduction. An instance of the adverse effect of grazing in this respect may be quoted in the case of a demarcated plot 200 square ft. in area in a river-bed in the Siwaliks, containing when laid out 1,562 seedlings one year old, with a maximum height of 6 in.; this plot, which was in a grazed area, was kept under observation for five years, at the end of which time only eight seedlings with a maximum height of 8 in. survived, most of the remainder having been destroyed by grazing. For three years the seedlings lingered chiefly in tufts of tall grass, where they were protected from cattle, but these eventually died of suppression. Saplings which are kept down by grazing present a typical bushy appearance, forming strong root-systems and sending up numerous root-suckers which are themselves browsed down, so that a dense low bushy growth of sissoo may cover considerable stretches; instances of this are fairly common in the Duars.

ARTIFICIAL REPRODUCTION. The sissoo can be grown from ordinary cuttings or from root cuttings. Such methods, however, are not in general vogue, as the tree can be raised so easily from seed. Plantations of root-suckers have proved highly successful in the dry climate of the Etawah district. United Provinces, and this form of propagation is worth further attention. In selecting sites for plantations care should be taken to avoid stiff clay soil, on which the trees, if they survive. remain stunted. Irrigation promotes the most rapid growth, and in the Punjab irrigated plantations, of which the oldest and most important is the Changa Manga plantation, have been in existence for many years and are being extended considerably. An account of the methods adopted in forming and working irrigated plantations is given below. Natural irrigation, in whole or in part, is secured in the case of *sailaba* plantations, formed on alluvial land adjacent to rivers, which receives occasional flood water; a short account of one of these plantations is also given below. It has already been shown, in connexion with the development of the seedling, that good results can be attained without irrigation provided thorough weeding with loosening of the soil is carried out until the plants are well out of the reach of weeds: indeed, it may be said that in any form of sissoo plantation thorough weeding during the early years is essential. This weeding should commence after the seedlings have sent down their taproots, and not during the germination stages, otherwise they are liable to be loosened and washed away by rain or exposed to drought. As regards the actual method of raising plantations, direct sowing is so much more satisfactory than transplanting that it is the only method to be recommended on a large scale; and in order to facilitate weeding, line sowings are far preferable to any other form of sowing. Many existing plantations in different parts of India, it is true, have been raised by transplanting from nurseries, but in the majority of cases the success attained has hardly been commensurate with the high cost involved. As transplanting is sometimes necessary, however, for the filling of gaps or for roadsides, the best method of carrying out this operation, as indicated by the results of numerous experiments at Dehra Dun, may be indicated.

Transplanting. The pods should be sown in drills in seed-beds of light soil thoroughly worked up, and lightly covered with earth. The sowing should be carried out well before the rains (March–April in northern India), and the beds should be regularly and copiously watered by hand or by irrigation; regular weeding and loosening of the soil is necessary. If small transplants are required the drills should be 9 in. apart, running across the beds in the usual way. If large transplants of the second year are wanted the lines should run longitudinally along the beds, and should be about 18 in. apart, and the plants should be thinned out towards the end of the first season; watering should be more sparingly done in the second than in the first season, in order to render the plants hardier. Transplanting with entire stem and roots is successful only with small plants early in the first rains, before the taproot reaches too great a length. Transplanting with pruned stem and roots has invariably given better results, not only as regards the percentage of success, but also as regards the vigour of the plants after transplanting. The stem should be pruned down to a height of about 2 in. from ground-level and the taproot to a length of about 6 in. if transplanting is done in the first rains, or about 12 in. if it is done in the second rains. Plants up to 7 ft. in height or more which have been treated in this way have been transplanted with complete success, vigorous new shoots being produced from the base almost immediately and soon attaining the height which the plants would have reached if they had not been interfered with. The chief danger to be feared after transplanting is drought, and if watering can be done until the plants are established it will help matters. If watering can be done winter planting, when the plants are leafless, gives good results.

Various degrees of spacing have been adopted in sissoo plantations in India. Anything more than 8 ft. by 8 ft. is generally found to be too wide, resulting in low branching and crooked growth: even this is on the wide side, and 6 ft. by 6 ft. is preferable though more expensive. Spacing 5 ft. apart in lines 10 ft. apart has been found satisfactory, as this facilitates weeding along the lines.

Mr. S. H. Howard[1] has described a successful method of transplanting seedlings from the nursery, which was tried in Gorakhpur in 1917. Under this method sowing in the nursery is carried out in April, May, or June, and the nursery beds are watered until the rainy season begins. The seedlings are regularly weeded and tended, and reach a height of 5 to 6 ft. by June of the next year, by which time they are ready to plant out. Planting holes about 2 ft. broad and 2 ft. deep are prepared in March, and in June the earth is returned to the holes. The plants are dug up carefully on a rainy and cloudy day, care being taken not to damage the roots more than is necessary. All the leaves are then pulled off and the leafless plants are planted out. After about a month the soil is worked up round the plants, and in November, or whenever labour becomes plentiful, the grass round them is pulled up and the soil worked. Some plants may die down for about a foot or 18 in., but new shoots develop below this point. This method is particularly well adapted

[1] Ind. Forester, xliv (1918), p. 137.

for planting grassy blanks, the plants being large enough **to overtop the grass** from the beginning.

Unirrigated line sowings. Various experiments with unirrigated line sowings have been carried out at Dehra Dun. The best results have been attained by line sowings in combination with the cultivation of field crops, the crop employed for experimental purposes being the lesser millet or *mandwa* (*Eleusine coracana*), which grew to a height of about 3 ft. or more. The lines of sissoo were sown along with the crop in June, and the latter was reaped in October. It was found that if the field crops were sown continuously over the area the sissoo sowings were a failure, the plants dying of suppression: excellent results, however, were attained by leaving clear lines 2 ft. wide, along the centre of which sissoo pods were sown and lightly covered with earth, the intervening spaces being occupied by the crop (see Fig. 125). A spacing of 10 to 12 ft. between lines is sufficient, and 1 lb. of sissoo pods should suffice for 200 ft. of line. The weeding of the lines is carried out by the cultivator while the crops are on the ground. Cultivation of field crops between the lines of sissoo can be carried out without difficulty for at least a second year; this saves the cost of weeding. In this as in other forms of line sowings the plants require to be thinned out regularly where necessary from the end of the first year onwards.

Unirrigated line sowings without the aid of field crops are carried out in the same manner as with field crops, the ground being cleared and the earth well loosened along the lines with a hoe or plough; subsequent success depends largely on intensive weeding, which is more troublesome and expensive than in the case of sowings with field crops. The pods should be sown not long before the commencement of the rains. In some localities weeding cannot be done in the rains for want of labour, and experiments were accordingly carried out at Dehra Dun to ascertain if sissoo plants in line sowings made in an area covered with tall grass, as opposed to weed-growth, would escape suppression during the rains and stand the sudden exposure when the grass was cleared from the lines after the end of the rainy season. The experiment proved quite successful, and gave an indication of the procedure to be followed in sowing up grassy savannahs if cultivation with field crops is not feasible. The first step is to clear the grass and partially eradicate it by ploughing or digging along the lines to a width of 2 or 3 ft. some time before the rains set in, the sissoo pods being then sown along the lines. As soon as labour is available after the rains are over the lines should be cleared of grass sufficiently to afford the seedlings full overhead light, and kept clear throughout the dry season, the soil along the lines being kept loosened and free of weeds. Care is necessary, in the selection of savannah ground for afforestation with sissoo, to avoid areas with clay soil, of which certain grasses (e.g. *Imperata arundinacea* and *Eragrostis cynosuroides*) are often indicators.

Irrigated plantations. The best examples of irrigated sissoo plantations are to be found on the plains of the Punjab, where land originally covered with dry scrub jungle of *Capparis aphylla*, *Salvadora oleoides*, and *Prosopis spicigera* has been made to produce flourishing plantations yielding a high out-turn of fuel and a fair quantity of timber. The oldest of these plantations is that of Changa Manga, watered by the Bari Doab canal in the Lahore district. Originally an area of 780 acres was taken up in 1866, but large extensions have been made subsequently. In 1916 the plantation had a gross area, including roads, rest-house compound, &c., of 9,605 acres and a wooded area of 9,097 acres. Many different species were tried at first, and it was only after numerous experiments that sissoo was decided on as the most suitable species for furnishing the requisite supplies of good fuel and useful timber. Other irrigated plantations have been commenced in the Punjab within recent years. In 1918 there were six new plantations, either started or about to be started, namely Kot Lakhpat (1,965 acres) and Tera (837 acres) on the Upper Bari Doab canal; Chichawatni (10,930 acres) and Khanewal (17,708 acres) on the Lower Bari Doab canal; Pir Mahal (15,000 acres) on the Lower Chenab canal; and Daphar (7,200 acres) on the Upper Jhelum canal. The areas of the last two are roughly tentative; they had not been started in 1918.

The preliminary work of laying out an irrigated plantation is carried out by the Irrigation Department, which constructs the distributaries leading from the main canal. In the case of the newer plantations, for purposes of irrigation control the area is divided into *chaks* or main subdivisions, each of which contains several compartments. A compartment may comprise two or more irrigation 'squares', and may be divided by watercourses (*khals*) into fields for irrigation purposes. In the Changa Manga plantation there are no *chaks* or squares. The working scheme for the new Khanewal plantation in the Multan district prescribes compartments as nearly as possible 50 acres in area, each comprising two squares of 25 acres each: each compartment is divided into three fields watered by three secondary *khals*. Each *khal* has on either side of it, and running parallel and close to it, a *pasel* or subsidiary channel which takes water from the *khal* and distributes it into the plantation trenches: the construction of *pasels* obviates the necessity for making openings in the *khal* at more points than is necessary. In the new Khanewal plantation the dimensions laid down for the secondary *khals* are $\frac{4+3}{2} = 3\frac{1}{2}$ ft. mean breadth by 1 ft. depth, and those of the *pasels* are $\frac{2+1}{2} = 1\frac{1}{2}$ ft. mean breadth by 1 ft. depth. The ultimate irrigation trenches are 1 ft. by 1 ft. in section. In Khanewal and Kot Lakhpat they are dug 10 ft. apart, in Changa Manga 11 ft. apart, and in Tera 15 ft. apart, the distances being measured from centre to centre. The secondary *khals*, *pasels*, and trenches are dug by the Forest Department. The estimate of earth-work for a compartment of 50 acres in the Khanewal plantation is as follows:

			cub. ft.
3 secondary *khals*	1,980 ft. × $3\frac{1}{2}$ ft. × 1 ft.	=	20,790
7 *pasels*	1,980 ft. × $1\frac{1}{2}$ ft. × 1 ft.	=	20,790
196 trenches	990 ft. × 1 ft. × 1 ft.	=	194,040
		Total	235,620

Various methods of carrying out the sowings and irrigating them have been tried, but the method now universally adopted as being the only really successful one is to throw up the soil excavated from the trench in the form of a ridge running alongside the trench; a small berm 3 or 4 in. wide, raised an inch or two above the level of the ground, is made between the trench and the ridge, and on this berm the seed is sown. As a rule 60 to 80 lb. of seed have been used per acre, but recently 40 lb. per acre has been tried in

Kot Lakhpat plantation and found to be sufficient. The best results are obtained by sowing from March to May; sowing may continue till September, but the plants from the later sowings are less vigorous than those from the earlier ones. Figs. 126 and 127 show sowings one and two years old.

The success of the plantation depends largely on the extent to which irrigation can be carried out and the regularity with which it can be effected in the dry season. It is a recognized principle that field cultivation has prior claim to water, so that the plantations do not always receive as much as they should. In the Kot Lakhpat plantation experience so far has been that the maximum number of times an area may be expected to be flooded during the year of sowing is seven times, while the average is considerably less, some areas having received no water since the first year and the crop having died in consequence. As the plantation becomes older less water is required, but irrigation should never be suspended for any length of time, as the trees invariably die off: it must continue regularly throughout the life of the plantation. Irrigation is carried out as far as possible throughout the whole year, though it is scarcely necessary from November to February; most water is required from April to June. The irrigation consists not only in filling the trenches but also in flooding the whole area above ground-level: young sowings, however, are not flooded, only the trenches being filled with water. In the Kot Lakhpat plantation the main channel which supplies the plantation is designed to flood the whole area between April 1 and September 30 to a total depth above ground-level equivalent to 3 ft. for the period, but actually the amount of water obtained may be considerably less. It is estimated that for a young plantation the minimum total depth of water possible during the hot weather months, April 1 to June 30, is about 1·7 ft. for the period, while if possible a depth of 2·5 ft. should be obtained: the latter is now arranged for as a minimum in Changa Manga. If the monsoon is favourable little or no irrigation may be necessary from July to October. In most parts of Changa Manga the effect of irrigation is to saturate the soil to a depth of several feet; only on the higher parts is saturation not so deep.

Irrigation is the dominating factor in an irrigated plantation, the size of which has to be limited to the area which can be irrigated successfully during April, May, and June, when if flooding to a total depth of anything much less than 2½ ft. is not carried out failure is almost certain. All other works must give way to irrigation in order to seize the opportunity of obtaining water whenever it is available, workmen being taken off other works for the time being to attend to it. The watercourses and trenches are regularly reopened whenever necessary. The earth cleared from the trenches is thrown on to the spaces between them except where sowing is to be carried out, when it is heaped up in a ridge on one side.

The irrigated plantations of the Punjab are worked under the system of coppice-with-standards. The question of the rotation has not yet been finally settled. In the case of Changa Manga regular fellings were commenced in 1881–2, but owing to labour and other difficulties work under the working plans was always in arrears, and for practical purposes the plantation may be considered to have passed through two rotations, one of sixteen years and a second of twenty-two years up to 1918–19. In the latest revised working

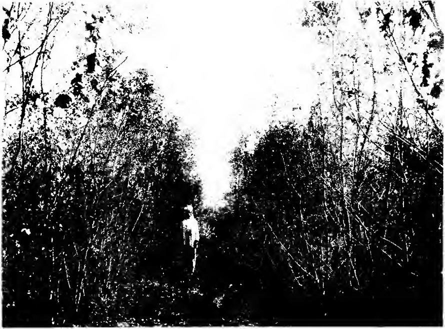

Fig. 127. Kot Lakhpat plantation : irrigated line sowings of sissoo 2 years old

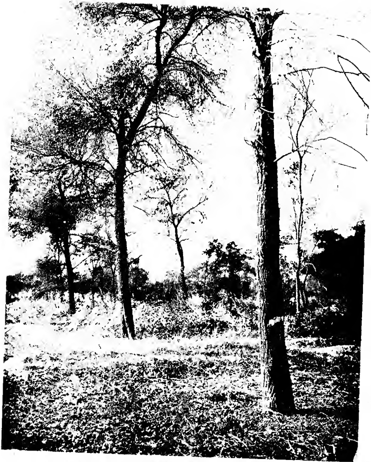

FIG. 128. Changa Manga plantation: coupe recently felled, showing sissoo standards left and felling refuse on the ground.

plan [1] a rotation of twenty years has been adopted, from 1916–17 to 1935–6. In the case of the newer plantations it is proposed to sow up the whole area in fifteen years, but it may be decided later to adopt a longer rotation. In fixing the rotation it should be borne in mind that the value of the timber increases greatly with the size of the logs obtained: on the other hand, large numbers of standards disappear owing to windfall and to the fungus attacks already mentioned, while it is not always practicable to remove all dead material scattered over the area, for which reason it is unsafe to adopt too long a rotation. In the revised Changa Manga working plan trees are considered to be fully mature after three rotations, that is, in sixty years. The number of standards aimed at is 15 to 20 per acre. The dressing of stools in cutting the coppice has now been abandoned, as it has been found to possess no advantage. Figs. 128 and 129 show two coupes in Changa Manga.

The Changa Manga plantation affords an interesting example of the spread of a subsidiary species by the agency of water and of birds. Once sissoo had been decided on as the most suitable species the intention was to make the plantation one mainly if not entirely of that species, and although there exist survivals of various other kinds of trees experimented with, the plantation in its earlier days consisted almost entirely of sissoo. Among the species planted on a small scale was the mulberry, *Morus alba*; the fruits of this tree are greedily eaten by starlings (*Pastor roseus*), which visit the plantation in large flocks at the time they ripen from the end of March to the end of April, and the seeds are widely scattered, particularly in the newly felled coupes, since the birds have a preference, as roosting places, for the standards left in these coupes. In addition the seed is largely spread by water during irrigation, and it is probable that the mulberry may have been introduced originally to a considerable extent from trees in the submontane tract by the irrigation canal: at all events, in some of the newly formed plantations the mulberry is making its appearance by this agency. The mulberry seed is spread to a limited extent by jackals and by human beings, but these are minor agencies. The mulberry being more shade-bearing and faster growing than the sissoo, and having a great capacity for regenerating, has spread throughout the plantation to such an extent that it now forms a considerably greater part of the crop than the sissoo, and were it not that special measures are taken to favour the sissoo it would he largely if not entirely ousted by the mulberry. At first the mulberry was looked on as a dangerous weed, but now it is regarded as a useful adjunct to the sissoo. Although its wood is of less value than that of the sissoo both as timber and as fuel, its more rapid growth compensates to some extent for this, while its shade-bearing character enables it to occupy ground under the sissoo which would otherwise be wasted, thus helping to swell the out-turn of the plantation. Fig. 130 shows mulberry coppice under sissoo standards. Silviculturally the mulberry acts as a useful soil-protector and promotes straighter and cleaner growth in the sissoo. In order to prevent the suppression of the sissoo and to maintain a sufficient proportion of that species, it is necessary to carry out repeated cleanings in the young coupes by cutting back the growth of mulberry in the interests of the seedling or coppice reproduction of the sissoo. Under the latest revised Changa Manga working plan the maintenance of the proportion of sissoo is provided for by clearing the mulberry and weeds in strips about 20 ft. wide and 100 ft. apart from centre to centre and cleaning repeatedly for three or four years along these strips. Three thinnings are also prescribed during the course of the rotation, at 6, 11, and 16 years of age respectively. Experiments have shown that natural reproduction of sissoo by seed can be obtained successfully merely by clearing the ground in newly felled coupes and carrying out periodical weedings and cleanings in order to free the seedlings which appear: a fair amount of reproduction is also obtained from root-suckers. Where further reproduction is required seeds are sown in the original lines alongside the trenches, which are reopened. It was formerly the practice to pile up the brushwood left after the fellings and burn it, but experience has shown that this is unnecessary, since it has been found to be cheaper and to cause less damage if the brushwood is merely piled up and left unburnt in the spaces between the trenches, in which case sufficient seedling and sucker reproduction comes up readily and the refuse rots within three or four years. Only where *kána* grass (*Saccharum Munja*) is very dense and the standards are few in number is burning carried out to facilitate the stubbing out of the grass, an operation which is necessary to prevent the suppression of young crops.

---

[1] **Revised Working Plan for the Changa Manga Plantation**, R. N. Parker, 1917.

The following summarizes the year's programme of work in an irrigated plantation in the Punjab:

April to June. Irrigation, opening trenches, stubbing out *kána* grass.
July to September. Opening trenches, weeding, cleaning, stubbing out *kána* grass, and opening trenches in areas recently felled over.
October to December. House and road repairs.
December to March. Clearing silt, repairing watercourses, and opening trenches.

Some figures of yield from the Changa Manga plantation are given below under 'rate of growth and out-turn'. Owing to the amount of experimental work necessary at first, the cost of this plantation was considerably higher than it would have been if experience had not had to be bought. Estimates for new irrigated plantations can now be framed with a fair degree of accuracy. In the working scheme for the Khanewal plantation the rates adopted in the estimate are: (1) construction of main and branch watercourses, Rs. 0–10–6 per acre; (2) construction of secondary watercourses, *pasels*, and trenches, Rs. 12 per acre; (3) collection and carriage of seed, Re. 1 per maund (82 lb.); (4) sowing, Rs. 2–2–0 per acre. Further expenditure is estimated for in connexion with roads, buildings, boundaries, repairs to watercourses, irrigation rental (Rs. 2–12–0 per acre per annum), and other items. In the earlier years the land not required for sowing is leased for agriculture, the initial expenditure being thus recouped in part.

Mr. R. N. Parker has worked out, in the revised working plan, details showing the financial position of the Changa Manga plantation from its commencement in the year 1867–8 down to the year 1915–16, allowing interest at 4 per cent. per annum on capital expenditure. By the year 1881–2, when regular working was commenced, the capital invested, with interest added, amounted to Rs. 6,73,769, of which Rs. 1,25,499 represented the value of the

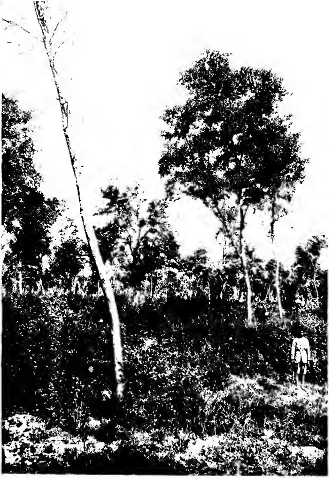

FIG. 129. Changa Manga plantation: coupe shewing sissoo standards and coppice 6 months old.

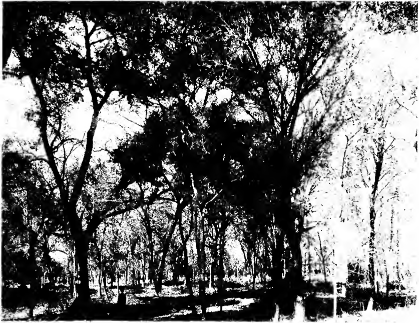

Fig. 130. Changa Manga plantation: sissoo standards over mulberry coppice 16 years old.

land. By 1898–9 the financial position was at its worst, the accumulated arrears of interest amounting to Rs. 4,78,018. With the second rotation, however, the position began to improve, and by 1913–14 the whole of the arrears of interest had been paid off and the plantation had just paid 4 per cent. on all capital invested in it, leaving Rs. 17,710 as profit. The position continues to improve at a rate at which the whole capital could be paid off within a few years, leaving a property of great value.

An independent calculation made with the view of ascertaining the rate of interest yielded by the plantation by the end of 1913–14 determined the rate of interest to be 4·67 per cent. The method employed was to ascertain at what rate of interest (*a*) and (*b*) are equal, where (*a*) represents the value at the outset of the annual profits and of the present estimated value of the property less the value at the outset of the annual losses, and (*b*) represents the value at the outset of the original value of the property and of all capital expenditure incurred. In round figures the values with interest at 4·67 per cent. are as follows :

	Rs.
(*a*) Value at outset of annual profits and of present estimated value of property	4,18,200
Value at outset of annual losses	31,200
Difference	3,87,000
(*b*) Value at outset of original value of property and of capital expenditure	3,87,000

This calculation probably errs on the side of safety : not only was the present value of the land over-stated, but no revenue was allowed for until the first fellings commenced in 1881–2, although the receipts up to that year exceeded Rs. 1,00,000 from grass, grazing, cotton cultivation, and other items.

These figures are sufficient to indicate that irrigated plantations formed and managed on rational lines have every prospect of yielding a fair return on the capital invested.

Sailaba plantations. These are plantations formed on the alluvial ground thrown up along the banks of rivers and subject, in part at least, to occasional flooding. The oldest plantation of this kind is the Shadera-Jugian plantation on the banks of the Ravi river near Lahore, where the rainfall is about 18 in. This plantation was commenced in 1865, and the area now amounts to some 1,400 acres. The soil is recent alluvium (*sailaba*) of a fairly light and sandy nature. The subsoil water at the driest season is about 6 to 15 ft. below the surface. A large proportion of the area is liable to inundation from the river during exceptionally high floods, but immersion is never long continued. Various methods of sowing and planting were tried when the plantation was formed ; these included sowing broadcast or in patches or lines of various spacing, as well as the transplanting of seedlings and root-cuttings. As far as can be ascertained from records the best results were attained by transplanting seedlings and by line sowings. Failures occurred mainly in waterlogged places, while some damage was done by floods when the seedlings were small. It is interesting to note that the growth has been best in the more elevated portions where the water-level is some 12 to 15 ft. below ground surface. The system of management applied so far has been coppice-with-standards with a coppice rotation of fifteen years, 15 to 20 standards being left per acre. As in Changa Manga, mulberry has spread over the plantation,

TABLE 1. Normal growing stock of sissoo seedling crops

Age. years.	Number of trees per acre.	Mean diameter at 4½ ft. from ground. in.	Mean height. ft.	Solid volume of growing stock per acre.		
				Material over 2 in. diameter. cub. ft.	**Faggots 1 in. to 2 in. diameter. cub. ft.**	**Brushwood under 1 in. diameter. cub. ft.**
I Quality.						
5	1,028	3·5	21·2	198	18	20
10	350	6.5	38·7	765	63	77
15	130	9·3	52·8	1,600	126	160
20	88	11·7	62·0	2,642	196	265
II Quality.						
5	1,200	2·9	18·0	146	11	15
10	460	5·4	33·0	536	40	57
15	—	7·8	45·0	1,124	79	120
20	—	9·8	53·0	1,829	125	195
III Quality.						
5	—	2·3	14·8	112	8	12
10	570	4·5	27·4	402	27	43
15	295	6·4	38·0	823	53	87
20	230	8·1	45·4	1,310	83	139

TABLE 2. Yield of fuel, sissoo seedling crops

Yield of fuel from 1 acre clear-felled.

Age. years.	Material over 2 in. diameter, stacked volume. cub. ft.	Faggots 1 in. to 2 in. diameter, stacked volume. cub. ft.	Brushwood under 1 in. diameter, solid volume.[1] cub. ft.	Total, solid volume.[1] cub. ft.	Mean annual increment, solid volume. cub. ft.
I Quality.					
5	325	100	20	220	44
10	1,255	356	77	844	84
15	2,625	706	160	1,770	118
20	4,333	1,102	265	2,917	145
II Quality.					
5	247	69	14	167	33
10	928	243	56	625	62
15	1,965	499	117	1,321	88
20	3,225	794	197	2,168	108
III Quality.					
5	184	46	11	123	24
10	660	157	40	442	44
15	1,350	303	82	902	60
20	2,150	468	130	1,434	71

Reducing factors.

100 cub. ft. stacked = 57 cub. ft. solid for fuel over 2 in. diameter.
100 cub. ft. stacked = 17 cub. ft. solid for fuel under 2 in. diameter.
Brushwood estimated at 10 per cent. of total out-turn.
Loss in conversion estimated at 7 per cent. of total out-turn.

increasing its yield; in the young coupes the sissoo has to be protected against the mulberry by means of cleanings. Wind is a serious cause of damage, chiefly to standards left in recently felled coupes: the fungus *Fomes lucidus* has also been responsible for much mortality among the trees. As regards in **Changa Manga** plantation.

---

[1] These are the figures as published: there appears to be a slight discrepancy on comparing some of them with the corresponding figures in Table I.

		Volume of normal series of age gradations in coupes of 1 acre each.					
Total of all classes. cub. ft.	Mean annual increment. cub. ft.	Material over 2 in. diameter.	Faggots 1 in. to 2 in. diameter.	Brushwood under 1 in. diameter.	Total of all classes.	Mean annual increment.	Age. years.
							I Quality.
236	47	444	39	48	531	106	5
905	90	2,998	253	305	3.556	355	10
1,886	126	9,216	749	827	10,792	719	15
3,103	155	20,294	1,587	1,938	23,819	1,190	20
							II Quality.
172	34	326	25	33	384	77	5
633	63	2,127	162	228	2,514	251	10
1,322	88	6,509	477	693	7.679	512	15
2,149	107	14.264	1,007	1,519	16.990	839	20
							III Quality.
132	26	258	17	25	300	60	5
472	47	1,626	110	170	1.906	190	10
963	64	4,859	423	513	5,795	386	15
1,532	76	10,384	777	1,100	12.261	613	20

in Changa Manga plantation.

Yield of fuel from 1 acre with 15 standards reserved.

Material over 2 in. diameter, stacked volume. cub. ft.	Faggots 1 in. to 2 in. diameter, stacked volume. cub. ft.	Brushwood under 1 in. diameter, solid volume. cub. ft.	Total, solid volume. cub. ft.	Mean annual increment, solid volume. cub. ft.	Age. years.
					I Quality.
310	94	19	209	42	5
1,180	319	72	792	79	10
2,430	622	148	1,633	109	15
4,000	960	244	2,684	134	20
					II Quality.
240	66	14	162	32	5
880	225	53	592	59	10
1,845	450	112	1,239	82	15
3,000	700	183	2,012	100	20
					III Quality.
180	43	11	119	24	5
630	145	38	421	42	10
1,275	270	77	849	56	15
2,020	408	122	1,342	67	20

out-turn, this plantation compares favourably with Changa Manga, in spite of the fact that the latter is regularly irrigated; the out-turn during the first rotation amounted to 230 cub. ft. stacked per acre per annum, including brushwood, or 200 cub. ft. exeluding it, as against about 160 cub. ft. for Changa Manga. During the first rotation the plantation yielded a net surplus of Rs. 9–6–7 per acre of wooded area per annum.

Silvicultural treatment. The silvicultural treatment of the sissoo in irrigated plantations has already been described: the system adopted in the Punjab is coppice-with-standards, seedling reproduction to replenish the existing crop being obtained both naturally, by clearing the ground and weeding the young crop, and artificially where necessary by sowing along the original lines. The value of a shade-bearer to mix with the sissoo has been alluded to. The mulberry serves this purpose well, provided it is kept in check by the necessary cleanings. Other species might be suggested, such as *Eugenia Jambolana, Ougeinia dalbergioides, Schleichera trijuga*, and in moist places *Bischoffia javanica*.

The case of natural riverain forests presents some difficulty, owing to the unstable condition of much of the land on which they are situated. It is obvious that as long as the land is likely to disappear through erosion it is not worth while undertaking special regenerative operations on it; Nature carries out these herself by throwing up new land and producing new crops of sissoo in compensation for those destroyed. In such unstable lands the only course possible is to utilize all material as soon as it becomes marketable, by extracting all saleable dead and fallen trees at frequent intervals and all growing trees when they reach exploitable size. It is quite certain that the sissoo cannot as a rule be relied on to regenerate itself in the actual coupes, as these are usually covered with dense grass and weed-growth. Actually the riverain sissoo forests of the sub-Himalayan tract are worked for the most part either by selection fellings or, as in the case of some of the Ganges islands, by simple coppice on a rotation of twenty years, belts being left unfelled along the edges adjacent to the river. The correct procedure with regard to the working of riverain tracts as high forest appears to be to divide them into two classes: (1) unstable land subject to erosion; and (2) stable land, which seems to be reasonably safe from river action for many years. The unstable lands would be worked in the manner already indicated. On the unstable lands, on the other hand, special regenerative operations should be undertaken: it is difficult to see how this could be effected satisfactorily except by clear-felling with artificial reproduction, with or without the aid of field crops. With each revision of the working plan it may be necessary to transfer areas from the stable to the unstable class, and vice versa; the greater the proportion of land which can be allotted to the stable class the more profitable will be the working, since the more intensive treatment possible in this class must necessarily produce a higher return. Climber-cutting should be executed over both classes. In the stable class regular cleanings and thinnings will be necessary, but in the unstable class a large expenditure on such works is not justified. In the latter class, however, if the crops are in no immediate danger of being washed away, thinnings, especially if they pay their way, are most desirable in order to bring the crops more quickly to maturity; they could be made conveniently along with the principal felling under a short cycle of say ten years.

RATE OF GROWTH AND OUT-TURN. The rate of growth of sissoo varies so much according to conditions that it will be advisable to consider available statistics separately for: (1) irrigated plantations; (2) unirrigated (including *sailaba*) plantations; and (3) natural crops.

1. *Irrigated plantations*. Some figures have been given above, in connexion with the development of seedlings and saplings, showing the rapid growth of young plants where irrigation is combined with weeding, in one case a maximum height of nearly 20 ft. having been attained in three years. Figures of out-turn for mature irrigated plantations are as yet confined to the Changa Manga plantation, but here general averages are difficult to obtain owing to the varying yield in different localities, and to the fact that the crops

have been felled at different ages and that the mixture of mulberry has an appreciable effect on the yield.

The statements on pp. 312–13 give an abstract of a series of figures compiled by Mr. B. O. Coventry[1] from measurements of seedling crops in the Changa Manga plantation, made when the plantation was cut over for the first time.

It is estimated that in this plantation seedling trees reach a girth of 4 ft. on an average in about twenty-five to thirty years.

As regards coppice crops in Changa Manga, the following measurements were recorded by Mr. A. Smythies in 1895 :[2]

Dalbergia Sissoo : coppice measurements, Changa Manga plantation.

Age.	Mean height.	Mean girth.		Age.	Mean height.	Mean girth.	
years.	ft.	ft.	in.	years.	ft.	ft.	in.
1	7·2	0	2	9	27·0	1	4·5
2	10·8	0	3·4	10	32·8	1	9·5
3	14·7	0	5	11	33·1	1	5·6
4	15·5	0	6	12	33·7	1	10·1
5	19·3	0	8·7	13	37·5	2	2·9
6	21·5	0	9·7	14	39·8	2	2·4
7	23·9	1	0·7	15	37·4	2	0
8	27·7	1	4·4				

Although statistics from the Changa Manga plantation exhibit great variation in the out-turn from different coupes, they show clearly that the yield has risen very considerably during the second rotation. This is due partly to the fact that the coupes of the first rotation consisted of seedling crops and those of the second rotation of coppice crops, and partly to the larger admixture of mulberry and the general increase in the density of the crop and the fertility of the soil during the second rotation. The revised working plan quotes the following figures illustrating this increase in the yield :

Dalbergia Sissoo : comparative yield of crops in the first and second rotations, Changa Manga.

Compartment No.	Age at felling.		Yield per acre per annum, stacked volume, thick firewood only.	
	1st rotation.	2nd rotation.	1st rotation.	2nd rotation.
	years.	years.	cub. ft.	cub. ft.
Various combined	15·0	15	137	246
41	15·5	15	101	178
45	15·5	16	99	201
46	16·5	16	142	212
58	17·5	18	116	260

The following statement, compiled from details given in the revised working plan, of the out-turn in each coupe during twenty years of the second (coppice-with-standards) rotation in the Changa Manga plantation shows an approximate average obtained by plotting all coupe out-turns of different ages and constructing mean curves :

---

[1] Ind. Forester, xxv (1899), pp. 488–94.

[2] *Ibid.* xxi (1895), p. 288.

Approximate average out-turn, Changa Manga plantation, **1896–7 to 1915–16.**

	Average out-turn per acre.				**Average out-turn per acre per annum.**			
	Stacked volume.			Solid volume, all classes.	**Stacked volume.**			**Solid volume, all classes.**
Age. years.	Thick fuel. cub. ft.	Thin fuel. cub. ft.	Total. cub. ft.	cub. ft.	**Thick fuel. cub. ft.**	**Thin fuel. cub. ft.**	**Total. cub. ft.**	**cub. ft.**
Sissoo and mulberry.								
12	2,350	750	3,100	1,100	**196**	**62**	**258**	**92**
13	2,550	800	3,350	1,220	**195**	**62**	**258**	**94**
14	2,760	850	3,610	1,330	**197**	**61**	**258**	**95**
15	2,980	890	3,870	1,450	**199**	**59**	**258**	**97**
16	3,200	920	4,120	1,560	**200**	**58**	**258**	**98**
17	3,400	940	4,340	1,680	**200**	**55**	**255**	**99**
18	3,600	960	4,560	1,800	**200**	**53**	**253**	**100**
19	3,800	980	4,780	1,900	**200**	**52**	**252**	**100**
20	4,000	1,000	5,000	2,000	**200**	**50**	**250**	**100**
21	4,200	1,000	5,200	2,120	**200**	**48**	**248**	**101**
22	4,400	1,000	5,400	2,240	**200**	**45**	**245**	**102**
Almost pure sissoo.								
16	1,816	491	2,307	840	113	31	144	53

Note.—The factors now employed for conversion from stacked to solid volume are 0·43 for thick fuel and 0·12 for thin fuel.

These figures cannot be accepted as in any way representative of pure sissoo out-turns, since the great majority of the coupes probably contained a larger proportion of mulberry than of sissoo. The figures for almost pure sissoo, in the last line, represent the average of only three compartments, aggregating 340 acres.

2. *Unirrigated (including sailaba) plantations.* Some figures have been quoted above, in connexion with the development of seedlings and saplings, showing the rapid rate of growth attained by young plants even without any irrigation, provided that regular weeding and loosening of the soil is carried out; these figures show that a maximum height of nearly 14 ft. in three years has been attained under these conditions in line sowings at Dehra Dun.

The following figures show the early growth of transplants in four experimental plantations formed at Dehra Dun in 1912:

Nature of transplants.	Height at end of 3rd season (dating from year of sowing). ft. in. ft. in.	Percentage of survivals at end of 3rd season. per cent.
(1) Transplanted first rains: entire stem and roots	2 0 to 10 3	82
(2) Transplanted first rains: entire stem and roots	5 0 to 13 0	47
(3) Transplanted first rains: pruned stem and roots	7 8 to 13 3	100
(4) Transplanted second rains: pruned stem and roots	maximum 5 6	100

The ground was hoed up and weeded prior to transplanting, but no weeding or watering was done afterwards. Nos. (2) and (3) adjoined each other: Nos. (1) and (4) were on somewhat stiff soil.

A sample plot measured in 1918 in a plantation forty-two years old in the Gorakhpur district, United Provinces, showed a mean girth of 4 ft. 7 in., a mean height of 97 ft., and a timber volume of 1,800 cub. ft. standing and 600 cub. ft. removed in thinning.

The following figures give the results of measurements of trees and crops in the plantations of the Thapal Grant estate, Saharanpur district, United Provinces, in 1907 :

Age.	Number of trees per acre.	Mean girth.		Mean height.
years.		ft.	in.	ft.
4	—	0	7·8	17·6
6	557	0	11·3	25·1
7	482	1	1·6	31·3
16	—	3	0·3	40·0 (average of 140 trees along sides of paths)

Measurements made by Mr. A. L. McIntire in 1885 in the Shahdera-Jugian *sailaba* plantation gave the following results :

Age.	Number of trees per acre (thinned crops).	Mean girth at 4 ft. from ground.		Mean height.	Mean solid volume per tree, material over 2 in. diameter.
years.		ft.	in.	ft.	cub. ft.
10	250	1	8	40	4·34
12	250	2	3	45	5·38
14	160	2	6	45	8·40
17	150	3	0	50	11·80
18–19	Standards isolated one year previously	3	4	53	14·50

As already mentioned, the out-turn from this plantation during the first rotation of fifteen years amounted to 230 cub. ft. stacked per acre per annum including brushwood, or 200 cub. ft. excluding it.

The Jhelum *sailaba* plantations gave a girth of 4 ft. at thirty years (Gamble).

3. *Natural crops*. Statistics relating to the rate of growth and out-turn of natural sissoo crops are as yet somewhat scanty. A commencement was made by the Forest Research Institute in 1910–11 in the establishment of sample plots to be measured periodically, and these should in time furnish useful statistics. Estimates in working plans are based on ring-countings ; it is true that the rings on stumps are at times tolerably clear, but they cannot always be relied on to give accurate results. The working plan of the Ganges (now Lansdowne) forest division, United Provinces, estimates a girth increment for alluvial sissoo on the Ganges islands of 1·7 in. per annum, giving a girth of 3 ft. in twenty-one years. The Dehra Dun working plan estimates that it will take 75 and 100 years to produce trees 4½ and 6 ft. in girth respectively in the alluvial forests of the Dun. Mr. F. Gleadow (quoted by Gamble) reported measurements of nearly 900 trees in the natural forests of Oudh, which for an average age of 15½ years gave a mean girth of 35 in. and a mean height of 50 ft.

The following statement shows the results of five years' growth in girth and height in the case of three sample plots laid out by the Forest Research Institute in young alluvial crops on sand and shingle in a dry river bed at Dholkund in the Saharanpur Siwaliks, where the normal rainfall does not exceed 45 in. :

Dalbergia Sissoo: girth and height measurements in natural young crops, Siwaliks.

	Girth.					Height.				
	First measurement.		Remeasurement after 5 years.		Mean annual girth increment for period.	First measurement.		Remeasurement after 5 years.		Mean annual height increment for period.
	Mean.	Maximum.	Mean.	Maximum.		Mean.	Maximum.	Mean.	Maximum.	
No.	in.	in.	in.	in.	in.	ft.	ft.	ft.	ft.	ft.
1	—	7·2	7·0	11·5	0·86[1]	10	15	24	33	3·6[1] 2·8[2]
2	8·6	—	11·6	—	0·6	20	—	27	—	1·4
3	13·5	—	19·1	—	1·1	33	—	36	—	0·6

[1] Largest stems only.

[2] Average of all stems.

In the moister localities the growth is probably a good deal faster: but in estimating the age of natural crops due allowance must be made for the conditions under which they have developed in early youth, since the growth may be checked for years by adverse influences such as grazing, weeds, &c. Assuming that the young plants have overcome such obstructions and have commenced their normal development, their subsequent growth is rapid up to middle age, after which it appears to slow down.

2. **Dalbergia latifolia**, Roxb. Blackwood, rosewood. Vern. *Sitsal*, Beng., Oudh: *Shisham*, Mar.; *Sissu*, Guz.; *Biti*, Kan.; *Jitengi*, Tel.; *Itti*, Tam., Mal.; *Thothagatti*, Tam. (Fig. 131.)

A large deciduous (nearly evergreen) tree with a full rounded crown. Bark fairly thin, grey, exfoliating in thin longitudinal flakes. The tree somewhat resembles *D. Sissoo*, but has denser and darker foliage, the leaflets being orbicular and obtuse or emarginate instead of rhomboidal or broad ovate and acuminate; it remains in leaf longer than *D. Sissoo*. Sapwood small, yellow; heartwood dark purple with black streaks. The wood is very hard, close grained, strong, durable and ornamental, and is used for a large number of purposes, such as furniture, panelling, ornamental work, ordnance work, agricultural implements, &c. It is exported to Europe under the name of rosewood or Bombay blackwood. It is a good shade tree for coffee. Under favourable conditions the tree reaches large dimensions. In Coorg Mr. H. Tireman has recorded girth measurements up to 15 ft. 5 in. and estimated heights up to 130 ft.

DISTRIBUTION AND HABITAT. The sub-Himalayan tract from Oudh (Gonda and Bahraich) to Sikkim, Chota Nagpur, central, western, and southern India. Although often found in considerable abundance the tree is not typically gregarious like *D. Sissoo*, but grows more or less scattered in mixed deciduous forests. Exceptionally it is found gregarious in patches on alluvial flats, as in the Dangs forests of Surat, Bombay. In the Western Ghats and in the fairly moist deciduous forests of southern India it attains large dimensions. In Bombay it occurs at various elevations up to 3,000 ft., associated with teak, *Terminalia tomentosa*, and other trees, and with bamboos, in mixed deciduous forest; as a rule it forms only a small percentage of the crop. It reaches its best development on deep moist soil at moderate elevations. Talbot says it is indigenous in the dry savannah forests of Khandesh on trap, and that it ascends to 3,700 ft. in the Akrani, mixed with teak, *Ougeinia dalbergioides*, and *Zizyphus Jujuba*; here it is usually a small tree owing to the unfavourable conditions of soil and climate. In Madras it occurs in many districts, but perhaps reaches its best development on the western slopes of the Nilgiris up to 4,000 ft., and on the Anamalais up to 4,500 ft., in mixed deciduous forests associated with teak, *Terminalia tomentosa*, *T. paniculata*, *Lagerstroemia lanceolata*, *Anogeissus latifolia*, *Xylia xylocarpa*, and other trees, often with bamboos: it is most common in comparatively moist situations near streams. On the Anamalai slopes of South Coimbatore trees of very large dimensions, with a girth up to 20 ft. and a clear bole up to 70 ft., are sometimes found. It is also found in fair quantity and of large dimensions in North and South Malabar. Elsewhere in Madras it often occurs in drier types of forest, where it does not attain large dimensions. In Mysore it is found scattered in mixed deciduous forest. In Coorg it occurs chiefly in deciduous forest of the moister type up to 4,000 ft. elevation or even higher, attaining its largest size (sound trees up to 7 ft. girth and 100 ft. height) in moist localities in association with *Bambusa arundinacea*. Bourdillon says it is widely distributed in Travancore between sea-level and 4,000 ft., though less common at the lower elevations and nowhere abundant; he says it is found in grass forest in company with teak, and sometimes in the drier parts associated with evergreen trees.

In the Central Provinces it is fairly widely distributed in mixed deciduous forests, though nowhere very abundant: its most important companions are teak, *Terminalia tomentosa*, *Lagerstroemia parviflora*, *Anogeissus latifolia*, and *Ougeinia dalbergioides*. It attains its largest dimensions (5 to 6 ft. in girth) in Chanda, but trees over 4½ ft. in girth are seldom sound. In Bihar and Orissa the tree is somewhat scattered and does not reach large dimensions; in Chota Nagpur it is commonest on cool aspects and along streams (Haines). In the United Provinces it is sparsely scattered in the dry deciduous forests of Bundelkhand and adjacent tracts, and also along the sub-Himalayan belt in the Gonda and Bahraich districts, chiefly in mixed deciduous forest, but sometimes in sal forest; here it reaches its northern limit, and is of small size.

The blackwood grows on a variety of geological formations, including gneiss, trap, laterite, boulder deposits, and alluvial formations, but it requires good drainage, and reaches its best development where the soil is deep and moist, particularly in the neighbourhood of perennial streams. It will grow fairly well on black cotton soil and also accommodates itself to poor dry stony soil, where, however, it does not reach large dimensions. In its natural habitat the absolute maximum shade temperature varies from 95° to 118° F., the absolute minimum from 32° to 60° F., and the normal rainfall from 30 to over 200 in.

LEAF-SHEDDING, FLOWERING, AND FRUITING. In dry localities the leaves are shed about February–March, the new leaves appearing in April–May. In moister localities the tree is seldom quite leafless. The flowering season is variously recorded. Brandis (northern and central India) says April (with the new leaves); Bourdillon (Travancore) says January–February; Talbot says April–May (with the new leaves) in the drier parts of Bombay, but adds that in moist localities (Kanara) it does not flower regularly or abundantly, and as far as is known only in August; Haines (Central Provinces and Chota

Nagpur) says September, when in full leaf, and Foulkes (**Walayer working** plan, South Malabar) gives the same month. It is possible that the variation in the recorded dates of flowering may be due to some confusion between the two closely allied species, or varieties, *D. latifolia* and *D. sissoides*. **Mr. H.** Tireman informs me that in Coorg the former flowers in September, the fruits ripening in March–April, while a variety, the latter presumably, flowers in March, the fruits ripening in June.

The flowers are pure white, in lax panicles 2–4 in. long. The pods ripen from December to April, according to locality, and hang some time on the tree, the majority falling at the beginning of the monsoon, thus escaping damage from forest fires. The flat indehiscent pods (Fig. 133, *a*) are 1·5–3 in. long by 0·5–0·75 in. broad, one- to three-, rarely four-seeded. The seeds (Fig. 133, *b*) are flat, reniform, 0·25–0·35 in. by 0·15–0·2 in., reddish brown, hard, smooth, shiny; testa coriaceous, fairly hard, brittle when dry, thicker than in *D. Sissoo*. Records of seed-years show that it does not seed so regularly or abundantly as *D. Sissoo*. Tests carried out at Dehra Dun showed a high percentage of germination, though a considerable proportion of the seed lost its vitality when kept for one year.

GERMINATION (Fig. 133, *c–g*). Epigeous. The radicle emerges from one end of the seed and curves downwards; the hypocotyl arches and pushes its way through the valves of the indehiscent pod, which become soft when soaked. The cotyledons are carried up above ground, either leaving the testa in the pod or carrying it up and dropping it when they expand.

THE SEEDLING (Fig. 133).

Roots: primary root long, not conspicuously thickened, terete, tapering, wiry, yellow or whitish at first, turning brown: lateral roots numerous, moderately long, fine, fibrous, distributed down main root: nodules present. *Hypocotyl* distinct from root, 1–2·5 in. long, more or less quadrangular and grooved, often tapering slightly upwards, greenish white, turning green then brown, glabrous, arched during germination. *Cotyledons*: petiole up to 0·06 in. long. Lamina 0·6–0·8 in. by 0·4–0·5 in., foliaceous, somewhat fleshy, reniform, with an angular projection on the basal half of the incurved side, apex rounded, base sub-sagittate, entire, glabrous, bright green above, paler beneath, midrib distinct, depressed, lateral veins somewhat obscure. *Stem* erect, terete, wiry, zigzag at the nodes, green turning brown, glabrous; internodes 0·3–1·3 in. long. *Leaves* alternate, compound, first two to five usually trifoliate, subsequent leaves 5-foliate, then 7-foliate, and sometimes 9-foliate in first season. Stipules 0·1–0·15 in. long, linear falcate, acute or acuminate, stipels absent. Trifoliate leaves with petiole 0·5–0·8 in. long, slender, glabrous; leaflets very shortly petiolulate, elliptical, ovate or obovate emarginate, entire, glabrous: terminal leaflet 0·5–0·9 in. by 0·3–0·7 in., lateral leaflets opposite or subopposite, 0·5–0·7 in. by 0·4–0·5 in. Subsequent leaves with rachis up to 4·5 in. long; leaflets shortly petiolulate, elliptical ovate or obovate or orbicular, sometimes emarginate, entire, glabrous; terminal leaflet up to 1·7 by 1·3 in., lateral leaflets alternate, smaller than terminal leaflet, up to 1·6 by 1 in.

The growth of the seedling is moderate during the first year, but in the second and subsequent years it is rapid under favourable conditions. Development is greatly stimulated by weeding and watering, particularly the former when accompanied by periodical loosening of the soil. Plants raised at Dehra Dun in broadcast sowings regularly weeded but not watered showed the following maximum heights at the end of the first four seasons: (1) 1 ft. 2 in.,

(2) 7 ft., (3) 12 ft. 9 in., (4) 14 ft. 6 in. Seedlings grown in unweeded sowings showed much slower growth. As illustrating the beneficial effects of cultivation on the growth of young plants, Mr. H. Tireman gives the measurements of six trees six years old planted in a coffee estate in Coorg, and constantly cultivated with the coffee : these varied from 17 ft. 9 in. to 24 ft. 9 in. in height and from 7 to 11½ in. in girth. In the same locality seedlings four years old resulting from sowings in blanks and merely kept free from overhead shade, without cultivation, varied from 2 ft. to 2 ft. 9 in. in height. The seedling requires porous soil, developing poorly or dying off on stiff badly-drained ground. A long taproot is formed at an early age, and may attain a length of 2 ft. or more by the end of the first season. Growth ceases during December, January, and part of February ; the seedlings are leafless in January–February, the new leaves appearing in March. In early youth the seedlings are somewhat tender both to frost and to drought, but later they are more hardy. The light requirements of the seedling are not so pronounced as in the case of *D. Sissoo* : partial shade from a hot sun in early youth protects and favours them, but overhead light greatly stimulates their development from the second year onwards. Fig. 132 shows a seedling five months old.

SILVICULTURAL CHARACTERS. The blackwood stands a fair amount of shade, particularly in youth, but may be classed as a moderate light-demander, since it benefits greatly by overhead light : if grown in too open a position it is apt to become crooked and branchy. It is more tender to frost than *D. Sissoo*, and on that account it has not proved a success in the 'Changa Manga plantation. As regards drought, seedlings in exposed situations suffer considerably in their early stages, but the tree is decidedly drought-resistant ; it was not affected in the severe drought of 1899–1900 in the Deccan. The seedlings and saplings are readily browsed by cattle and goats, but light grazing may, it is said, be beneficial in areas where the growth of grass and weeds is heavy. As already mentioned, the tree grows best on well-drained deep moist soil, but has good capacity for growing on poor dry soils, where, however, it does not reach large dimensions. It does not tolerate bad drainage. Talbot observes that it withstands annual fires well ; nevertheless it benefits greatly from fire-protection. It is less fire-resisting than teak, and is often killed outright by the crown fires characteristic of lantana-infested tracts.

It coppices well, though the season of cutting appears to influence the production of shoots. Experiments in North Chanda showed good coppicing power up to July, after which a falling off was noticeable : the percentage of stools which sent up coppice-shoots was—April to July, 100 per cent. each ; August, 80 per cent. ; September, 25 per cent.

The roots, like those of *D. Sissoo*, are dimorphous. A long taproot is formed in the younger stages ; this becomes thickened, and other main roots, as well as numerous smaller nutrition roots and fibrous rootlets without buds, are also produced, growing downwards into the ground. In addition long superficial propagation roots with buds spread radially outwards, running horizontally not far below the surface or at times even along the surface of the ground ; from these numerous suckers are sent up, particularly where the roots are exposed or wounded, old trees being often surrounded by quantities of suckers, many of which develop into trees. These suckers are most plentiful in situations exposed to the light, for example on the edges of roads, fire-lines, boundary lines, and the like. Mr. S. H. Koorders[1] describes the prolific growth of root-suckers in a plantation formed in 1875–6 in the Banjumas district of Java on a low ridge on stiff reddish brown clay soil of poor quality, cracked in dry weather, with a hard pan of ironstone below the surface. The trees in sixteen years (1891) had reached a height of 49 to 72 ft.[2] Every tree was surrounded with a thicket of suckers, the largest of which were 30 ft. high. One tree 50 ft. high and 1 ft. 11 in. in diameter at breast height was selected for the number of suckers produced, and dug up and found to have 200 suckers up to 30 ft. high; the largest had developed a perfect root-system of its own and was throwing out horizontal roots with the view of producing new suckers. For a poor locality of the kind described the growth is so rapid as almost to give rise to a suspicion of a mistake either in the identity of the species or in the age of the plantation: the species, it is stated, was determined by Dr. J. G. Boer, Conservator of the Royal Herbarium at Leyden.

NATURAL REPRODUCTION. Under natural conditions germination takes place in the early part of the rainy season. The various factors affecting the establishment of natural reproduction by seed require further study. So far as is shown by experiments carried out hitherto, the chief cause of mortality in the germinating stages and during the early development of the seedling after germination is drought in situations exposed to a hot sun. Where the pods have been covered with earth, or are protected from the sun in open places by a moderate growth of grass or in the forest by shade which is not too dense, conditions for natural reproduction are usually favourable; the most favourable conditions are moderate shade with bare ground and loose fairly moist soil. For the subsequent development of natural saplings the best results are obtained by the plentiful admission of overhead light. Heavy bamboo cover is found to suppress the seedlings and prevent their development, while much mortality is caused by dense weed-growth. In the Madras Forest Report of 1915–16 it is stated that in East Kurnool the cutting back of the bamboos to favour tree species resulted in a profuse mass of blackwood seedlings. In forests protected from fire and grazing natural reproduction is usually good under light shade, while it is sometimes abundant on open grassy places and on ridges, though in such cases it is probable that much of the reproduction consists of root-suckers.

ARTIFICIAL REPRODUCTION. The tree can be propagated artificially from cuttings put in early in the rains, by planting root-suckers or sections of lateral roots, or from seed by direct sowing or by transplanting from the nursery. Various experiments in sowing and planting have been recorded, and it has generally been found that in dry situations drought is the chief danger to be feared; fairly good results have been obtained in some localities, particularly in the moist forests of Coorg, by sowing under partial shade in the forest on patches cleared and burnt. Sowing in *kumris* (shifting cultivation) also gives much promise. This species would appear to be a suitable one for raising as an under-story in teak plantations provided the teak is sufficiently thinned out.

Various experiments in the artificial propagation of blackwood have been carried out at Dehra Dun; the results showed that direct sowing is preferable to transplanting, as the mortality may be considerable if dry weather follows the transplanting. In either case it is unnecessary to extract the seeds from the pods, though it is advisable to break the pods into sections, each containing one seed.

---

[1] Ind. Forester, xx (1894), p. 282.

[2] Dimensions, which in the original are given in metres, have been converted to feet and inches.

In order to raise plants for transplanting the seed should be sown in well-raised seed-beds of porous sandy loam in drills about 9 in. apart or in longitudinal lines about 18 in. apart, according as transplanting is to be done during the first or the second season. The sowing should be carried out in March or April, the beds being regularly watered and weeded and protected from the sun during the heat of the day. The seedlings may be planted out early in the first rains either with entire roots and stems or with stems pruned down to about 2 in. and taproots to about 6 in. The seedlings may be kept in the nursery till the early part of the second rains; in this case they should be thinned out during the cold season, and before transplanting the stem should be pruned down to about 2 in. and the taproot to about 12 in. Transplanting with pruned stem and roots has given better results than transplanting without pruning. Owing to the risk of mortality from drought it is always advisable where possible to water the transplants during dry weather for some time after planting.

So far as direct sowings are concerned, the great secret of success is regular weeding and loosening of the soil; excellent results have been attained in this way at Dehra Dun without any watering at all. In actual practice the best results were attained by line sowings, preferably with the aid of field crops. A spacing of about 12 ft. between lines should be sufficient, the lines being well ploughed or hoed up to a width of about 18 in. and the seed sown shortly before the commencement of the rains and lightly covered with earth. For every 100 ft. of line 5 oz. of pods should suffice. Weeding and loosening of the soil should be commenced before the weeds become dense, as it has been found that the sudden removal of heavy weed-growth from over the seedlings may cause them to die of drought.

Experiments in line sowings with field crops, the crop employed being the lesser millet or *mandwa* (*Eleusine coracana*), showed that the best results are obtained by leaving a clear strip about 2 ft. wide along the lines, the field crops being sown in the intervening spaces. If the crops are sown over the whole ground the seedlings are liable to suffer from suppression and also from the sudden exposure when the crops are reaped. Regular weeding is carried out along the lines by the cultivator, and hence if the cultivation of the crops is continued between the lines for a second season the cost of establishing the plantation is much reduced.

Experiments were carried out at Dehra Dun to ascertain if line sowings left unweeded during the rains would survive the suppression and sudden exposure if the weeds are removed after the rains. It was found that the seedlings survived well under a comparatively heavy growth of grass and weeds, and that they did not suffer from the removal of the cover provided this was carried out after the growing season was over, in the early part of the cold weather. This experiment is of importance in that it is not always possible to obtain labour for weeding in the rains, whereas weeding and soil-loosening, even if carried out only in the dry season, stimulates the development of the plants considerably.

Mr. L. S. Osmaston [1] has described the results of experimental sowings of *Dalbergia latifolia* and other species in the Bombay Deccan, in a locality where the normal rainfall is slightly under 20 in. and the absolute maximum and minimum temperatures are 114° and 48° F. respectively. In dry localities of the kind, he found that the only successful method was by means of sowings in combination with field crops. The crops employed were sesamum, cotton, and the lesser hemp. The tree seed was sown with the agricultural sowing implements of the country. It was found more satisfactory to raise the plantations by the agency of lessees than by departmental agency. Two different methods were tried: (1) the first year the lessee was allowed to cultivate with field crops, the tree seeds as well as field crops being sown in the second year and weeding being carried out twice in the year the tree seeds were sown; one line of tree seeds was sown to three of field crops, and the lines being about 1 ft. apart the distance between the lines of tree seeds was about 4 ft.; (2) under the second method the tree seeds were sown in strips 4 ft. broad, in four lines 1 ft. apart, alternating with strips of field crops 8 ft. broad; during the second year the lessee cultivated field crops between the strips of tree seedlings and also weeded and sowed up blanks in the latter. The former of the two methods had only been recently tried, but the latter had given good results up to date, though the success of such operations must depend largely on the rainfall in any particular year. In these sowings a maximum height of 12 ft. and a maximum girth of 6 in. was attained in 3½ years. Where the work was carried out departmentally the total cost during the first three years (including collection and sowing of seed and weeding, but not including supervision) was Rs. 28–11–0 per acre: the receipts from the produce of the field crops was Rs. 32 per acre, leaving a net profit of Rs. 3–5–0 per acre.

Experiments at Dehra Dun have shown that the blackwood can be grown in irrigated plantations in the manner described for *Dalbergia Sissoo*. The blackwood, however, would probably be intended primarily for the production of timber and not of fuel, and it is not certain if the proportion and quality of the heartwood from trees grown in irrigated plantations would answer requirements.

Silvicultural treatment. Existing working plans usually prescribe either coppice-with-standards, in which blackwood is one of the species ordinarily reserved as standards, or else some form of selection fellings, the minimum exploitable girth being fixed as a rule at 6 ft. In either case it is usual to prescribe the artificial reproduction of the blackwood and other principal species to supplement natural reproduction where it is insufficient. Now that concentrated systems of exploitation and regeneration are gaining ground in India, the future treatment of this species will no doubt demand more intensive measures for artificial reproduction over definite areas in combination, if desired, with teak and other valuable species.

Rate of growth. The rate of growth of the blackwood under natural conditions is by no means fast. Working plans estimate that the trees reach an average girth of 6 ft. in 110 years in Kurnool and 160 years in North Kanara, while in the North Dangs of Surat a girth of 3½ ft. is estimated to be reached in 80 years. In Mysore a girth of 6 ft. is reckoned to be reached in 80 years.

---

[1] Ind. Forester, xxxiii (1907), p. 265.

Brandis gives 5 to 9 rings per inch of radius, corresponding to a mean annual girth increment of 0·7 to 1·26 in. Some of Gamble's specimens showed 8 rings per inch, or a mean annual girth increment of 0·78 in. He also quotes a statement by Mr. A. W. Lushington to the effect that 20 samples in Cochin territory on the Western Ghats gave an average of 3 rings per inch, indicating, as is natural, that the rate is faster in moist climates than in dry ones. A case of abnormally rapid growth in a plantation in Java has been referred to above, while figures of growth in youth have been given under 'the seedling'.

The following statement gives a summary of the results of ring-countings in the Ankola and Kalinaddi slopes forests of the North Kanara district, Bombay,[1] after converting to girth measurements, allowing for bark thickness, and constructing average curves :

Dalbergia latifolia : rate of growth in girth in high forests of the North Kanara district, Bombay.

	Girth.					Girth.			
Age.	Ankola high forest.		Kalinaddi slopes.		Age.	Ankola high forest.		Kalinaddi slopes.	
years.	ft.	in.	ft.	in.	years.	ft.	in.	ft.	in.
10	0	7	0	7	90	3	11	4	3
20	1	1	1	2	100	4	3	4	7
30	1	7	1	8	110	4	7	4	10
40	2	0	2	2	120	4	11	5	1
50	2	5	2	8	130	5	3	5	4
60	2	10	3	2	140	5	6	5	7
70	3	3	3	7	150	5	9	5	10
80	3	7	3	11					

Bark thickness 0·2 in.

As regards coppice, measurements made in 1916 in the Saitba coppice coupes, Kolhan, Bihar and Orissa, on poor hilly ground, gave the following results :

Dalbergia latifolia : rate of growth of coppice, Saitba.

Age.	Mean height.	Mean girth.	Age.	Mean height.	Mean girth.
years.	ft.	in.	years.	ft.	in.
2	4·5	1·8	10	20·5	7·7
4	9·5	3·6	12	23·5	9·0
6	13·5	5·0	14	26·5	10·3
8	17·0	6·4			

3. **Dalbergia sissoides**, Grah. Malabar blackwood. Vern. as for *D. latifolia*, viz. *Thothagatti*, Tam. ; *Itti*, Mal.

A southern Indian tree very closely allied to *D. latifolia*, occurring in Malabar, the Palnis, Anamalais, Madura, Tinnevelly, Travancore, and probably Coorg. It is a smaller tree than *D. latifolia*, with more numerous leaflets, and lighter coloured and less compact foliage : the young leaves of *D. latifolia* are dark green, while those of *D. sissoides* are pale green. Bourdillon[2] says the wood is readily distinguishable ; that of both species has a purple ground, but whereas that of *D. latifolia* is uniform in colour or veined with black or red lines, that of *D. sissoides* is much mixed with dark brown, and never has any tint of red in it; wood-cutters accordingly term the former *kar-itti* (dark blackwood) and the latter *vel-itti* (pale blackwood). Of the occurrence of the two trees in Travancore he says that speaking generally *D. latifolia* prefers the interior forests and *D. sissoides* the outer hill-slopes; the former ascends to a greater height, but the latter has been observed up to 2,000 ft. At lower elevations *D. sissoides* predominates, but *D. latifolia* is also found, and from the abundance of small plants of the latter it may be inferred that it was at one time more common in easily accessible places than it is now. In Travancore the flowers of *D. sissoides* appear with the new leaves in January–February, and the fruit ripens from October to January. Mr. H. Tireman says that in Coorg the flowers appear in March and the fruits ripen in June (presumably this species).

---

[1] Working Plans for the Ankola High Forest, Blocks xxiv and xxv, 1908, and the Kalinadd Slopes, Block xxvi, 1908–9, R. S. Pearson.

[2] Ind. Forester, xxxi (1905), p. 124.

4. **Dalbergia cultrata**, Grah. Burma blackwood. Vern. *Yindaik*, Burm.

A moderate-sized to large deciduous tree. Bark fairly smooth with short horizontal furrows. Heartwood black with dark purple streaks, very hard, used for ploughs, knife handles, &c. The wood is very handsome, and would be suitable for furniture and ornamental work, as in the case of the blackwood (*D. latifolia*).

DISTRIBUTION AND HABITAT. Throughout the greater part of Burma, in upper and lower mixed forests and *indaing* (dry dipterocarp) forest. It is also characteristic of certain classes of lower mixed forest approaching the savannah type; here it is associated with *Butea frondosa*, *Anogeissus acuminata*, *Careya arborea*, *Lagerstroemia Flos-Reginae*, *L. macrocarpa*, *Stephegyne parvifolia*, *Dalbergia purpurea*, and other trees, growing in low-lying tracts covered with dense tall savannah grass. It is not a gregarious tree, but is decidedly common, occurring scattered throughout the deciduous forests; it is a common companion of the teak both in upper and in lower mixed forest. In its natural habitat the absolute maximum shade temperature varies from 100° to 110° F., the absolute minimum from 40° to 50° F., and the normal rainfall from 40 to 100 in. or more.

LEAF-SHEDDING, FLOWERING, AND FRUITING. The tree is leafless in the hot season, the new leaves appearing about April. The white or pale pink flowers, in small panicles, appear with the young leaves. The pods (Fig. 134, *a*, *b*) ripen in the cold season and hang some time on the trees: they are brown, flat, 1 to 4 in. by 0·4 to 0·6 in., 1- to 3-seeded. About 250–300 seeds weigh 1 oz.

GERMINATION (Fig. 134, *c*–*g*). Epigeous. The radicle breaks through or between the valves of the pod, the hypocotyl arches, withdrawing the cotyledons in straightening, or in the case of small pods or sections of pods the valves may be carried up over the cotyledons. The testa is usually carried up, dropping with the expansion of the cotyledon

THE SEEDLING (Fig. 134).

Roots: primary root long, terete, tapering: lateral roots numerous, fibrous: nodules present. *Hypocotyl* distinct from root, 0·9–1·5 in. long, slightly compressed, tapering slightly upwards, green, tomentose. *Cotyledons* sub-sessile, plano-convex, somewhat fleshy, 0·4–0·45 in. by 0·2–0·25 in., reniform, the incurved margin indented, apex rounded, base sub-sagittate, entire, glabrous. *Stem* erect, terete, zigzag at the nodes, wiry, tomentose, green turning brown; internodes 0·5–0·9 in. long. *Leaves* compound, normally imparipinnate, but early leaves occasionally paripinnate, first pair opposite or sub-opposite, subsequent leaves alternate, early leaves with 7, rarely 5, later leaves of first season with 9 leaflets. Stipules under 0·1 in. long, lanceolate, acuminate, tomentose. Rachis 0·9–2·6 in. long, finally tomentose. Leaflets with petiolules up to 0·1 in. long, opposite in first few leaves, afterwards opposite, sub-opposite or alternate, 0·4–1·3 in. by 0·2–0·5 in., elliptical, or terminal leaflet sometimes obovate, apex acute or rounded, sometimes emarginate, mucronate, entire, bright green and glabrous above, paler and pubescent beneath, leaflets of earlier leaves smaller than those of later leaves, terminal leaflet often larger than lateral leaflets.

Little is yet known regarding the habits of the seedling, except that according to experiments carried out at Dehra Dun it appears capable of standing moderate shade, and in this respect resembles *D. latifolia* rather than *D. Sissoo*.

Silvicultural characters and reproduction. The silvicultural characters of this tree require further study, but as far as information goes at present they resemble in the main those of *D. latifolia*, which species *D. cultrata* also appears to resemble as regards the conditions necessary for successful reproduction, both natural and artificial.

5. **Dalbergia Oliveri,** Gamble. Burma rosewood. Vern. *Tamalan, tabauk*, Burm.

A moderate-sized to large deciduous tree, in general appearance not unlike the Burma padauk (*Pterocarpus macrocarpus*), but the leaflets are considerably smaller. The bark is yellowish grey, much resembling that of padauk, but the blaze is greenish yellow, quickly turning brown, and no red juice is exuded as in the padauk. The largest tree I have measured, in the Katha district, Upper Burma. had a girth of 6 ft. 9 in., a total height of 80 ft., and a clear bole of 50 ft. The tree is apt to form a low crown. The heartwood is hard and close grained, usually a rich red colour, though, like the red Andaman padauk, it is liable to fade if not polished. Good coloured pieces are very handsome, and are suitable for furniture and ornamental work. In parts of Upper Burma *D. Oliveri* is known as *tamalan-ni* (red *tamalan*) to distinguish it from *tamalan-byu* (white *tamalan*), which has been identified as *D. Hemsleyi*. Prain, a tree with a strong superficial resemblance to it, but having a whitish wood of no value. The Burmans also distinguish *tamalan-wa* or yellow *tamalan*, but this has also been identified as *D. Oliveri*; the distinction probably refers to some slight variation in the colour of the heartwood.

Distribution and habitat. In Burma, from Pegu northwards, chiefly in Upper Burma. The tree is not gregarious, but is found scattered in mixed deciduous forests of a dry type, often associated with teak and bamboos. It grows usually on hilly ground in localities similar to those occupied by *Pterocarpus macrocarpus*. It also occurs in *indaing* (dry dipterocarp) forest on laterite. It extends into the dry zone of Upper Burma, for example in the southern part of the Meiktila district; here it does not attain large dimensions. In its natural habitat the absolute maximum shade temperature varies from 104° to 110° F., the absolute minimum from 40° to 45° F., and the normal rainfall from 35 to 80 in.

Leaf-shedding, flowering, and fruiting. The tree is leafless in the early part of the hot season, the new leaves appearing in April. The panicles of white flowers appear with the new leaves. The pods (Fig. 135, *a*) ripen about February–March. They are brown, flat, 3–5 by 0·5–1 in., 1- or 2-seeded;

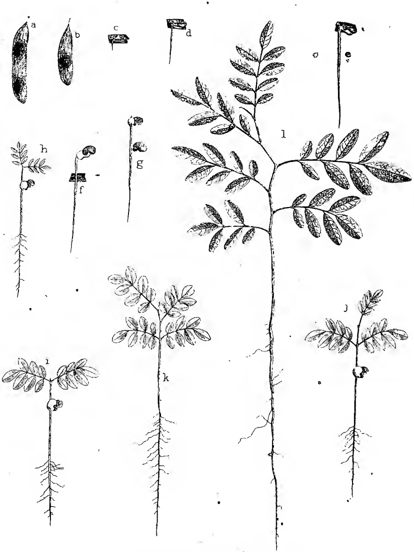

FIG. 134. *Dalbergia cultrata.* Seedling × ½.
a, *b*, fruits ; *c*–*g*, germination stages ; *h*–*l*, development of seedling to end of first season.

seeds dark brown, hard, flat, reniform, averaging 0·4 by 0·25 in., about 100 weighing 1 oz. Saplings six years old have seeded freely at Dehra Dun.

GERMINATION (Fig. 135, *b–d*). Epigeous. The radicle pushes its way through the valves of the indehiscent pod, which become soft when moistened; the hypocotyl arches and the cotyledons are withdrawn from the pod, the testa being either left in it or carried up over the cotyledons, dropping with their expansion.

THE SEEDLING (Fig. 135).

Roots: primary root long, moderately thick, terete, tapering, yellow: lateral roots moderate in number, fibrous; nodules present. *Hypocotyl* distinct from root, 1–1·2 in. long, slightly compressed, tapering upwards, white turning green. *Cotyledons*: petiole 0·05 in. long or less: lamina 0·4–0·5 in. by 0·25–0·3 in., plano-convex, somewhat fleshy, reniform with an angular projection near the base of the incurved side, apex rounded, entire, green, glabrous. *Stem* erect, terete, zigzag at the nodes, wiry, green, minutely pubescent; internodes 0·4–1 in. long. *Leaves* compound, imparipinnate, first pair opposite, subsequent leaves alternate, first few with 5 leaflets, the number increasing subsequently to about 13 leaflets by the end of the first season. Stipules 0·1–0·15 in. long, linear acuminate, pubescent; stipels absent. Rachis about 0·8 in. long in earliest leaves, increasing to about 4·5 in. in later leaves of the first season. Leaflets of early leaves usually opposite, of subsequent leaves alternate, with short petiolules up to 0·06 in. long, 0·4–1·5 in. by 0·25–0·8 in., elliptical or oblong, apex rounded or emarginate, base rounded, entire, glabrous above, minutely pubescent below; the leaflets increase in size with successive leaves.

Experiments carried out at Dehra Dun show that as regards the development of the seedling the requirements of this species agree with those of the better known species. Thus weeds are inimical to good development, which is favoured by weeding and loosening of the soil and by moderate watering; excess of moisture causes the seedlings to damp off during and after germination. With regular weeding and moderate watering seedlings at Dehra Dun reached a maximum height of about 1 ft. by the end of the first season and over 2 ft. by the end of the second season. Transplanted seedlings, which were not watered after transplanting, attained a height of 7 to 11 ft. by the end of the fourth season, including the year of sowing. A fairly long taproot is formed. At Dehra Dun seedlings shed their leaves in January, and new growth commences about March. The seedlings were found to be much subject to insect damage during and shortly after germination. They do not suffer so badly from frost as might be expected in a species growing naturally in localities where frost is unknown.

SILVICULTURAL CHARACTERS. So far as observations go at present, the silvicultural characters of this tree appear to resemble somewhat those of *D. latifolia*. During youth it stands a fair amount of shade, but requires overhead light for its best development.

NATURAL REPRODUCTION. Experiments at Dehra Dun indicate that, like other species of *Dalbergia*, the conditions necessary for successful reproduction are bare ground, loose soil, and absence of weed-growth. Under natural conditions the seed germinates early in the rains. In the mixed forests of Upper Burma in which the tree occurs, natural reproduction has usually been found to be good, young trees appearing in fair quantity under light shade, very much as in the case of *D. latifolia* in the Indian Peninsula.

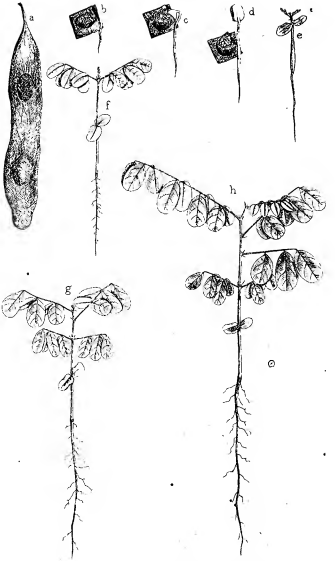

Fig. 135. *Dalbergia Oliveri*. Seedling × $\frac{5}{8}$.
a, fruit; *b–d*, germination stages; *e–h*, development of seedling during first season.

Artificial reproduction. It is probable that the best results in the way of artificial reproduction would be attained by weeded line sowings, preferably with the aid of field crops, as in the case of *D. Sissoo* and *D. latifolia.* Numbers of plants have been successfully raised in boxes at Dehra Dun, the seed being sown in April; the result was the same whether the seed was extracted from the pod or the pods were sown whole. Some of the seedlings were transplanted with entire stem and roots during the first rains, and some were left until the second rains and transplanted, some with entire stem and roots, and others with stems pruned to 2 in. and taproots to 9 in.; in each case the operation was carried out with success.

6. PONGAMIA, Vent.

Pongamia glabra, Vent. Vern. *Papar, kanji,* Hind.; *Karanj,* Mar.; *Honge,* Kan.; *Ponga,* Tam.; *Kanga,* Tel.; *Thinwin,* Burm.

A moderate-sized nearly evergreen tree with a spreading shady crown and short bole; bark fairly thin, smooth, grey, yellowish inside. The wood, which is yellowish white, is not durable, and is used mainly for fuel. The tree is planted for shade and ornament throughout the greater part of India. The seeds yield a thick oil used for burning and as an application for skin diseases.

Distribution and habitat. Throughout the greater part of India and Burma, chiefly along streams and rivers; common near the sea-coast in beach and tidal forests. In the Andamans it is one of the characteristic species of the mixed forests of the littoral fringe; in the Sundarbans it occurs along the sand-hills near the coast, and elsewhere along the coasts of India and Burma it is locally common. It has been largely planted, and in many places has run wild, so that it is not always easy to determine if it is locally indigenous or not.

The tree is wonderfully adaptable as regards locality: although commonly found wild in the sandy beds of streams or along the sea-shore, thriving with its roots in fresh or salt water, it is grown successfully as a roadside tree in comparatively dry parts of the Indian Peninsula or on the alluvial plains of Northern India. In localities in which it is known to have been cultivated successfully the absolute maximum shade temperature varies from 100° to 120° F., the absolute minimum from under 30° to over 60° F., and the rainfall from 20 to over 100 in.

Leaf-shedding, flowering, and fruiting. The tree is almost evergreen, or is leafless or nearly so for a short time in May. Bourdillon says it drops its leaves several times during the year. The racemes of lilac flowers appear from April to June. The pods ripen from March to May the following year. The pods (Fig. 136, *a*) are 1·5–2 in. long by 1 in. broad, pointed at both ends, woody, indehiscent, yellowish grey when ripe, 1- or 2-seeded. The pods are easily opened by passing a knife along the suture. Seeds (Fig. 136, *b*), when solitary, 0·7–0·8 in. by 0·5–0·7 in., compressed, elliptical or reniform, wrinkled, reddish brown, testa leathery, easily cut; when there are two seeds in the pod they are flattened in contact, irregularly shaped, and angular. Tests carried out at Dehra Dun showed that the percentage of fertility is high, and that the seed retains its vitality at least a year if carefully stored.

Germination (Fig. 136, *c–g*). Hypogeous. The thick radicle emerges from one end of the seed, and the primary root attains some length before the plumule appears, the young shoot arching to extricate itself, and then straightening.

THE SEEDLING (Fig. 136).

Roots: primary root long, thick, terete, tapering, woody, whitish or light yellowish brown: lateral roots numerous, fibrous, distributed down main root: nodules present. *Hypocotyl* distinct from root, 0·4–0·5 in. long, thick, fleshy, compressed, green, glabrous, subterranean. *Cotyledons* sessile, 0·8–0·9 in. by 0·5 in., thick, fleshy, reniform, green, outer surface rounded, slightly rugose, inner flattened in contact. *Stem* erect, first internode compressed, later internodes terete, green, glabrous but young parts finely pubescent; internodes 0·6–3 in. long. *Leaves*, first two or three often abortive; normal leaves usually four or more simple, followed by trifoliate leaves till end of first season; 5-foliate leaves first produced in second season. Stipules 0·1 in. long, ovate falcate. Simple leaves with petiole 0·2–1·2 in. long, terete, glabrous; lamina 1·5–3 in. by 0·5–2·5 in., ovate acuminate, base rounded or truncate, entire, glabrous or young leaves finely pubescent. Trifoliate leaves with common petiole up to 2·5 in. long in first season, leaflets with petiolules 0·15–0·2 in. long, ovate acuminate, entire, glabrous, terminal leaflet 2·5–3·5 in. by 1·3–1·8 in., lateral leaflets opposite, somewhat smaller than terminal leaflet.

The growth of the seedling is fairly rapid. Nursery plants at Dehra Dun had a maximum height of 8 in. at the end of the first season and 4 ft. 8 in. at the end of the second season. A long stout taproot is developed at an early stage. Seedlings at Dehra Dun stand frost fairly well, the leaves being slightly touched but the stems being unaffected.

SILVICULTURAL CHARACTERS. The tree is a shade-bearer, and may be found growing naturally along watercourses under the shade of other trees. It resists drought well, having remained unaffected by the severe drought of 1899 and 1900 in the Indian Peninsula. It was badly damaged at Lahore in the abnormal frost of 1905, but ordinarily it is moderately frost-hardy. The tree produces root-suckers. It is frequently pollarded in southern India to furnish green manure. As already mentioned, it is not exacting as to locality. It grows best, however, in fairly moist situations on porous well-drained soil, thriving even on pure sand; it will grow on black cotton soil.

ARTIFICIAL REPRODUCTION. The tree is easily raised from seed or from cuttings. The seed may be sown in the nursery when it ripens, about April or May, and the seedlings will be ready to transplant early in the rains of the next year; in dry places the plants require to be watered regularly in dry weather for a few years. For forest purposes direct sowings in suitable localities would probably prove more successful than transplanting. In Coorg direct sowings have proved successful in the beds of streams, in which places it is a useful species to introduce.

7. ROBINIA, Linn.

Robinia Pseudacacia, Linn. Robinia, false acacia, locust tree.

A deciduous tree, with thick rough brown longitudinally furrowed bark and handsome pinnate-leaved foliage; the young shoots are smooth, purplish brown, armed with stout triangular stipular spines in pairs, which persist for some years. In America it usually attains a height of 40 to 60 ft. with a diameter of 1 to 1½ ft., while under the most favourable conditions it may reach a height of 80 ft. and a diameter of 3 ft.[1] In Europe it attains a height of 80 ft. and a girth of about 15 ft.[1] The wood is hard, with yellowish brown or reddish brown heartwood: in Europe it is largely used for wheel-spokes, fence-posts, vine-props, &c. In India the tree has proved of considerable value in the Punjab Himalaya, not only as a producer of fuel but also as a useful species for clothing bare slopes and fixing unstable ground, provided the soil is deep and porous.

---

[1] U. S. For. Service Cir., No. 64.

DISTRIBUTION AND HABITAT. The robinia is a native of North America and is indigenous in the Appalachian Mountains of the United States from Pennsylvania to Georgia, and in certain portions of eastern Indian Territory and Arkansas, but has become naturalized throughout the greater part of the United States east of the Rocky Mountains, as well as in Nova Scotia and Ontario. It has succeeded well south of the 38th parallel of latitude, thriving in regions characterized by a hot summer season: latterly, however, planting has been somewhat restricted owing to the ravages of the locust-borer (*Cyllene robiniae*, Forster), a beetle whose grubs bore into the wood. In America it is found in mixture with other trees or in pure crops on forest land that has been burnt over: it grows best on a deep well-drained fertile loam, but will grow on almost any soil except a wet heavy one; it shows good development on limestone. Elwes[2] says that all his observations in England go to show that robinia is essentially a lover of a hot, dry, and sandy soil, though it attains a large size and age only on a good sandy loam, and while tolerating lime it grows much better without it. The tree was introduced into France in 1601 by J. Robin (whence its name), and has become thoroughly naturalized in that country, particularly in the Garonne and Rhone valleys, also in Hungary, Belgium, southern Russia, Italy, the southern Alps, the Balkan States, and other localities, thriving best in regions where the summer is warm: in Europe it does not grow well at high altitudes. It grows particularly well on porous soil, and in Europe is frequently grown on new embankments, spoil-banks, loose hill-sides, and taluses, and thrives on the loose sandy soil of the coastal dunes of France; in Roumania it has proved a great success in fixing the moving sands of the Danube.

The robinia was introduced into India in the latter part of last century, and planting was commenced in the Punjab about 1890, and continued for many years at various elevations from the plains up to about 10,000 ft. It has done well at moderate elevations, that is, from 4,000 to 6,000 ft., on deep porous soil, but on dry shallow soil it has not come up to expectations as a possible species for afforesting bare slopes; in such places it exists to some extent, but remains stunted. It avoids stiff heavy soils. Its chief value lies in fixing embankments and places liable to landslips, provided the soil is deep and porous and not too dry: its power of producing root-suckers and fixing the soil is invaluable in such places. It is now a common tree about Simla, and has also been planted to a considerable extent about Jutogh, Dagshai, Sabathu, and other places. In the Kangra valley and at Dharmsala attempts to introduce robinia have not met with success, while in the Murree hills experience has shown that it has little chance of surviving the heat and drought from April to June at elevations below 5,000 ft. It has been introduced successfully in the hills of Burma, and grows well at Maymyo (about 3,500 ft.).

---

[1] Elwes and Henry, Trees of Great Britain and Ireland, vi. 1497.

[2] *loc. cit.*

The climatic conditions under which the tree will thrive in India are as yet insufficiently known. At Simla the absolute maximum and minimum shade temperatures are respectively 94° and 19° F. The normal rainfall is 63 in. at Simla and 57 in. at Maymyo.

LEAF-SHEDDING, FLOWERING, AND FRUITING. In the Himalaya the leaves commence turning yellow and falling by leaflets in September. Some trees are leafless by the end of October: others are not entirely leafless until early December. The new leaves appear in the beginning of April, and by the end of that month the trees are in full leaf. The fragrant white flowers, in pendulous racemes, appear in April, at which time the trees, whose young foliage is well out, are particularly handsome, and are visited by numerous bees for the sake of the honey which they obtain from the flowers. The pods form rapidly, ripening at the end of August and during September. The pods (Himalayan) are 1–5 in. long by 0·35–0·7 in. broad, flat, brown and glabrous outside, silvery white and shining inside, containing up to 16 seeds, which are 0·2 in. long, compressed, reniform, dark brown, firmly attached to the pod valves by funicles about 0·1 in. long. Some pods commence to dehisce shortly after ripening, but dehiscence continues tardily for three or four months, being favoured by dry weather. The pods fall at various times throughout the winter and the following hot season, particularly during strong winds and storms, which blow them to some distance from the tree; the majority of the pods remain on the trees throughout the greater part of the winter, and some remain hanging as late as the following June.

The tree produces flowers and fruits at an early age, plants three years old having been observed to produce them in the Simla hills; small root-suckers may often be found in flower and fruit.

In places with a heavy monsoon rainfall it has difficulty in ripening its seeds.

SILVICULTURAL CHARACTERS. In its native home and in Europe the robinia is a strong light-demander: the same applies in the Himalaya, where, however, on southern slopes trees may be found persisting under light shade, though their development is impeded. In England it is liable to be broken by wind, and also suffers considerably from late and early frosts; in France it appears to be better able to withstand frost, the young shoots becoming sufficiently lignified before the early frosts set in. In the Himalaya no serious frost damage has been noticed in the case of established trees, for although early frosts shrivel up those leaves which remain late on the trees, no real damage is done: seedlings, however, are somewhat sensitive during the first year, after which they are wonderfully hardy. At the higher elevations the tree is apt to suffer from snow-break. In France the robinia resists drought well, and has been found to be one of the most hardy species in hot dry summers. In the Himalaya it also resists drought well at elevations over 4,000–5,000 ft.; at low elevations on hot dry slopes the seedlings die of drought, surviving only in sheltered and comparatively moist situations. The robinia coppices freely and produces root-suckers in great abundance from its superficial roots, which often attain considerable length: the root-suckers are formed at an early age, plants three years old having been observed to produce them in the Simla hills.

NATURAL REPRODUCTION. In America the pods are retained on the trees well into the winter, and are carried long distances by the strong winter winds, and abundant reproduction often springs up on old fields or forest lands which have been burnt or cut over, resulting in many cases in pure crops: the robinia also propagates itself freely by means of root-suckers and stool-shoots, young crops killed by fire being resuscitated in this way. In France natural reproduction by seed takes place freely only on the loosest soils, as on sand-dunes. Wherever the tree has been introduced outside its natural home it exhibits its tendency to spread by means of root-suckers.

In the Himalaya the tree preserves its original characteristic of retaining its pods well into the winter, but strong winter winds do not occur regularly as in America, and the seed is not distributed to great distances. In this region seedling reproduction has not been observed, but the tree reproduces with great freedom by root-suckers, which often form regular thickets on the hill-sides: in nurseries, also, the portions of root left in the ground when the young plants are removed send up plentiful crops of vigorous shoots.

ARTIFICIAL REPRODUCTION. The tree may be propagated by seed or by root-cuttings; stem-cuttings planted in the rains are moderately successful, but cannot always be relied on. In Europe numerous cultivated varieties and some hybrids have been produced; some of these are successfully propagated by cuttings, but grafting is usually resorted to. In America it is customary to plant out in the spring nursery-raised seedlings one year old, their height varying from 1 to 3 ft.; it has been found advisable, before sowing the seeds in the nursery, to soak them for four or five days in water heated to a temperature of 150° to 160° F., the seed then being transferred straight from the water to the seed-bed. Owing to the wide-spreading root-system close planting is avoided in America unless early thinnings can be carried out: a spacing of at least 6 ft. by 6 ft. is adopted, except in the dry climate of the middle west, where a spacing of 6 ft. by 4 ft. or 8 ft. by 3 ft. is considered more suitable.

M. Seurre[1] considers that a good average spacing is one of 1·25 by 2 metres, while one of 2 by 2 metres could be adopted in exceptional cases of vigorous growth on fertile ground. He adds that when plantations languish during their early years, they should be coppiced at the age of three or four years in order to obtain good and abundant shoots.

Mr. G. S. Hart[2] has described the method found most successful for the cultivation of the robinia in the Simla hills, and the following passage may be quoted from his note:

> 'Direct sowings have been tried again and again on various aspects, at different elevations, and during different seasons, but have failed completely in all cases, and so it appears certain that the plants must be raised in nurseries.
>
> 'It has been found that sowings made in the beginning of the rains were not very successful, as the amount of moisture that they then experienced was apt to kill off the seedlings: the best time then for the necessary sowings, which should be light, is from the middle of September to the middle of March, according to the altitude, and this is equivalent to saying that the seed can be sown as soon as there is no further danger to be apprehended from frost. Drainage is the main point to be seen to in the construction of the nurseries, for an excess of water, but more particularly anything in the shape of stagnant water, is fatal to the young seedlings; the nurseries should therefore be made with small raised seed-beds surrounded by small trenches, and the amount of

---

[1] Bull. Soc. For. Franche-Comté et Belfort, xi (March 1911), p. 14.

[2] Ind. Forester, xxi (1895), p. 169.

> water given during the hot weather should be regulated by the appearance of the plants, care being taken to avoid any flooding of the nurseries and to see that no water remains standing in the beds. The seedlings commence germinating some three weeks after the sowings, and grow quickly, many of them attaining a height of over two feet by the break of the rains, and of over five feet by the end of the growing season, while exceptionally quick-growing specimens have been found to attain a height of eight feet six inches during this period: seedlings germinating late will naturally become more or less suppressed, but, nevertheless, it is inadvisable to attempt any rebedding during the rains, for this stops the growth of the larger and kills many of the smaller plants that are moved. Similarly to the sowings, the results of transplanting from the nurseries during the rains are not very satisfactory, and it is better to do this work during January and February, timing it so as to give the plants the benefit of the latter portion of the winter rains after they have been placed in their final situation. At first, plants of all sizes were put out into the plantations, but it was noticed that the smaller ones made very little progress during the first and sometimes also during the second year following their removal, while the large plants grew on without any such break: now, therefore, no trees under three feet six inches in height are used for transplanting, and all under these dimensions are rebedded into nurseries during January and February, and left there for another year.
>
> 'This transplanting and rebedding cannot be done without inflicting some injury on the roots, but, with the Robinia, this really does not matter; indeed, it is found that, while the transplants themselves do not suffer, the bits of the roots inadvertently left in the ground give rise to a crop of flourishing root-suckers during the following year, and these attain larger dimensions than the seedling plants.'

In the Simla hills the total cost of raising plants and putting them out comes to about Rs. 2 per 100 plants, and as the spacing adopted is usually 9 ft. by 6 ft. or 10 ft. by 6 ft. the cost per acre works out at about Rs. 15 to Rs. 16, or allowing for possible failures, say Rs. 20.

SILVICULTURAL TREATMENT. In America the tree does well in pure crops, though in the more arid regions it is considered advisable to mix with it soil-protective trees. In Europe it is usually worked as coppice often on a comparatively short rotation, and in the Himalayan plantations this method is also being followed with very successful results.

RATE OF GROWTH AND OUT-TURN. The growth of the robinia is rapid, but the tree is comparatively short-lived. In America, under favourable conditions, its average height-growth is 2 to 4 ft., and its diameter increment ¼ to ½ in. a year; as a rule the growth slows down between the fifteenth and twentieth years, though it may continue to be rapid for about 25 to 30 years. After the fiftieth year growth almost entirely ceases.[1] Illes says that in Hungary a plantation 50 years old produced 8,800 cubic ft. of timber per acre, the trees averaging 90 ft. in height and 10 in. in diameter.[2] A plantation in France, 50 years old, yielded 4,300 cubic ft. per acre.[3]

In the Simla hills an individual tree has been known to attain a height of over 20 ft. and a girth of 1 ft. 4 in. below the first branch in three years from the sowing of the seed (G. S. Hart). The yield per acre in a plantation 25 years old at Jutogh in the Simla hills was 2,000 cubic ft. stacked.

---

[1] U. S. For. Serv. Cir., No. 64.

[2] Unwin, Future Forest Trees.

[3] Bull. Soc. For. Franche-Comte et Belfort, x. 18.

INDEX TO SCIENTIFIC NAMES, VOLUME I

Acacia pennata, *Willd.*, 250
Acer, Tournef., 221.
    caesium, *Wall.*, 223.
    Campbellii, *Hook. f. and Th.*, 225.
    caudatum, *Wall.*, 221.
    cultratum, Wall., 225.
    Hookeri, *Miq.*, 221.
    isolobium, *Kurz*, 221.
    laevigatum, *Wall.*, 222.
    niveum, *Blume*, 221.
    oblongum, *Wall.*, 222.
    Papilio, *King*, 221.
    pentaponicum, *J. L. Stewart*, 222.
    pictum, *Thunb.*, 225.
    sikkimense, *Miq.*, 225.
    stachyophyllum, *Hiern.*, 221.
    Thomsoni, *Miq.*, 221.
    villosum, *Wall.*, 225.
Adansonia, Linn., 151.
    digitata, *Linn.*, 151.
Aegle, Correa, 167.
    Marmelos, *Correa*, 167.
Aesculus, Linn., 226.
    assamica, Griff., 229.
    indica, *Colebr.*, 226.
    punduana, *Wall.*, 229.
Ailanthus, Desf., 171.
    excelsa, *Roxb.*, 171.
    glandulosa, *Desf.*, 174.
    malabarica, *DC.*, 173.
Amoora, Roxb., 205
    cucullata, *Roxb.*, 205.
    Rohituka, *W. and A.*, 205.
ANACARDIACEAE, 235.
Anacardium, Rottb., 237.
    occidentale, *Linn.*, 237.
ANONACEAE, 8.
Azadirachta, Adr. Juss., 178.
    indica, *Adr. Juss.*, 178.

Balanocarpus, Bedd., 134.
    utilis, *Bedd.*, 134.
Berrya, Roxb., 162.
    Ammonilla, *Roxb.*, 162.
    mollis, Wall., 162.
BIXACEAE, 12.
Bombax, Linn., 135.
    anceps, Pierre, 145.
    cambodiense, Pierre, 145.
    Gossypium, Roxb., 12.
    heptaphyllum, Cav., 135.
    insigne, *Wall.*, 145.
    malabaricum, *DC.*, 135.
    scopulorum, *Dunn*, 146.
Boswellia, Roxb., 174.
    glabra, Roxb., 174.
    serrata, *Roxb.*, 174.
    thurifera, Colebr., 174.
Bouea, Meissner, 240.
    burmanica, *Griff.*, 240.
    oppositifolia, Meissn., 240.
Buchanania, Roxb., 240.
    Lanzan, Spreng., 240.
    latifolia, *Roxb.*, 240.
Bursera serrata, *Colebr.*, 174.
BURSERACEAE, 174.
Butea, Roxb., 257.
    frondosa, *Roxb.*, 257.
    superba, *Roxb.*, 250.

Calophyllum, Linn., 21.
    elatum, Bedd., 21.
    Inophyllum, *Linn.*, 21.
    polyanthum, *Wall.*, 21.
    spectabile, *Willd.*, 21.
    tomentosum, *Wight*, 21.
    Wightianum, *Wall.*, 21.
Cananga odorata, Hook. f. and Th., 9.
Canangium, Baill., 9.
    odoratum, *Baill.*, 9.
Canarium, Linn., 174.
CAPPARIDACEAE, 10.
Capparis, Linn., 12.
    aphylla, *Roth*, 12.
Carapa, Aublet, 186.
    moluccensis, *Lamk.*, 186.
    obovata, *Blume*, 187.
Cassia [illegible]dosa, *Ham.*, 250.
Cedrela, Linn., 194.
    microcarpa, *C. DC.*, 200.
    serrata, *Royle*, 199.
    Toona, *Roxb.*, 194.
CELASTRACEAE, 209.
Chickrassia, Adr. Juss., 191.
    tabularis, *Adr. Juss.*, 191.
    velutina, Roemer, 191.
Chloroxylon, DC., 200.
    Swietenia, *DC.*, 200.
Chukrasia, Adr. Juss., 191.
Citrus, Linn., 167.
    Aurantium, *Linn.*, 167.
    decumana, *Linn.*, 167.
    Hystrix, *DC.*, 167.
    medica, *Linn.*, 167.
Cochlospermum, Kunth., 12.
    Gossypium, *DC.*, 12.
Crataeva, Linn., 10.
    Nurvala, Ham., 10.
    religiosa, *Forst.*, 10.
    Roxburghii, R. Br., 10.
Cullenia, Wight, 151.
    excelsa, *Wight*, 151.

Dalbergia, Linn. f., 293.
    cultrata, *Grah.*, 326.
    lanceolaria, *Linn.*, 294.
    latifolia, *Roxb.*, 318.
    Oliveri, *Gamble*, 327.
    oujeinensis, Roxb., 273.
    paniculata, *Roxb.*, 294.
    sissoides, *Grah.*, 325.
    Sissoo, *Roxb.*, 294.
Derris scandens, *Bth.*, 250.

Desmodium, Desv., 250.
Dillenia, Linn., 1
    angusta, Roxb., 3.
    aurea, *Smith*, 1.
    indica, *Linn.*, 1.
    pentagyna, *Roxb.*, 3
    pilosa, Roxb., 3.
    pulcherrima, *Kurz*, 1.
    speciosa, Thunb., 1.
DILLENIACEAE, 1
DIPTEROCARPACEAE, 30.
Dipterocarpus, Gaertn. f., 35.
    alatus, *Roxb.*, 46.
    Baudii, Korth., 39.
    Bourdilloni, *Brandis*, 31.
    costatus, *Gaertn. f.*, 31.
    grandiflorus, Wall., 40.
    Griffithii, *Miq.*, 31.
    indicus, *Bedd.*, 37.
    laevis, Ham., 35.
    obtusifolius, *Teysm.*, 39.
    pilosus, *Roxb.*, 39.
    tuberculatus, *Roxb.*, 40
    turbinatus, *Gaertn. f.*, 35.
Dodonaea, Linn., 225.
    Burmanniana, DC., 225.
    viscosa, *Linn.*, 225.
Dryobalanops aromatica, *Gaertn. f.*, 30.
Durio, Linn., 151.
    zibethinus, *Linn.*, 151.
Dysoxylum, Blume, 204.
    binectariferum, *Hook. f.*, 204.
    glandulosum, Talb., 204.
    macrocarpum, Thw., 204.
    malabaricum, *Bedd.*, 204.

Echinocarpus, Blume, 166.
    dasycarpus, *Benth.*, 166.
Elaeodendron, Jacq. f., 210.
    glaucum, *Pers.*, 210.
    Roxburghii, W. and A., 210.
Entada scandens, *Bth.*, 250.
Eriodendron, DC., 150.
    anfractuosum, *DC.*, 150.
Erythrina, Linn., 264.
    indica, *Lam.*, 265.
    resupinata, *Roxb.*, 264.
    suberosa, *Roxb.*, 265.

Feronia Elephantum, *Correa*, 167.
Flacourtia, Commers., 12
    Ramontchi, *L'Hérit.*, 12.
    sapida, Roxb., 12.

Garcinia, Linn., 20
    Mangostana, *Linn.*, 20.
Garuga, Roxb., 176.
    pinnata, *Roxb.*, 176.
Glycosmis pentaphylla, *Correa*, 166.
Gordonia integrifolia, Roxb., 29.
Grewia, Linn., 164.
    elastica, *Royle*, 165.
    flavescens, *Juss.*, 164.
    Hainesiana, *Hole*, 164.
    laevigata, *Vahl*, 164.
    Microcos, *Linn.*, 166.
    oppositifolia, *Roxb.*, 164.
    populifolia, *Vahl*, 164.
    salvifolia, *Heyne*, 164.
    sapida, *Roxb.*, 164

Grewia (*continued*):
    tiliaefolia, *Vahl*, 165.
    vestita, Wall., 165.
GUTTIFERAE, 20.

Helicteres, Linn., 162.
    Isora, *Linn.*, 162.
Heritiera, Aiton, 153.
    acuminata, Wall., 160.
    Fomes, *Buch.*, 153.
    littoralis, *Dryand.*, 159.
    minor, Roxb., 153.
    Papilio, *Bedd.*, 160.
Hopea, Roxb., 47.
    glabra, *W. and A.*, 31.
    odorata, *Roxb.*, 47.
    parviflora, *Bedd.*, 48.
    racophloea, *Dyer*, 31.
    Wightiana, *Wall.*, 52.
Hydnocarpus, Gaertn., 13.
    inebrians, Wall., 13
    Wightiana, *Blume*, 13.

Ilex, Linn., 209.
    denticulata, *Wall.*, 209.
    dipyrena, *Wall.*, 209.
    insignis, *Hook. f.*, 209.
    Wightiana, *Wall.*, 209.
ILICINEAE, 209.
Indigofera, Linn., 250.

Kydia, Roxb., 146.
    calycina, *Roxb.*, 146.
    fraterna, Roxb., 146.
    Roxburghiana, Wight, 146

LEGUMINOSAE, 250.
Limonia acidissima, *Linn.*, 167.
Lophopetalum, Wight, 209.
    Wightianum, *Arn.*, 209.

MAGNOLIACEAE, 4.
MALVACEAE, 135.
Mangifera, Linn., 237.
    indica, *Linn.*, 237.
Melanorrhoea, Wall., 243.
    usitata, *Wall.*, 243.
Melia, Linn., 183.
    Azadirachta, Linn., 178.
    Azedarach, *Linn.*, 183.
    composita, *Willd.*, 186.
    indica, Brandis, 178.
    robusta, Roxb., 186.
MELIACEAE, 178.
Mesua, Linn., 23.
    coromandelina, Wight, 23.
    ferrea, *Linn.*, 23.
    pedunculata, Wight, 23.
    pulchella, Pl. and Trian., 23.
    Roxburghii, Wight, 23.
    sclerophylla, Thw., 23.
    speciosa, Choisy, 23.
Michelia, Linn., 4.
    aurantiaca, Wall., 7.
    Champaca, *Linn.*, 7.
    excelsa, *Blume*, 4.
    nilagirica, *Zenk.*, 4.
    oblonga, *Wall.*, 4.
Micromelium pubescens, *Blume*, 167.
Miliusa, Lesch., 8.
    velutina, *Hook. f. and Th.*, 8.

Millettia auriculata, *Baker*, 250.
 ,, racemosa, *Bth.*, 250.
Moringa, Lam., 249.
 oleifera, Lam., 249.
 pterygosperma, *Gaertn.*, 249.
MORINGACEAE, 249.
Mucuna macrocarpa, *Wall.*, 250.
Murraya exotica, *Linn.*, 166.
 ,, Koenigii, *Spr.*, 167.

Odina, Roxb., 245.
 Wodier, *Roxb.*, 245.
Ougeinia, Benth., 253.
 dalbergioides, *Benth.*, 253.

PAPILIONACEAE, 252.
Parashorea, Kurz. 134.
 stellata, *Kurz*, 134.
Pavia indica, Wall., 226.
Pentace, Hassk., 162.
 burmanica. *Kurz*, 162.
Pentacme, A. DC., 53.
 siamensis, Kurz. 53.
 suavis, *A. DC.*, 53.
Pistacia, Linn., 235.
 integerrima, *J. L. Stewart*, 235.
 mutica, *Fisch. and Mey.*, 236.
 vera, *Linn.*, 235.
Poeciloneuron, Bedd., 22.
 indicum, *Bedd.*, 22.
Polyalthia, Blume. 10.
 cerasoides, *Benth. and Hook. f.*, 10.
 fragrans. *Benth. and Hook. f.*, 10.
 longifolia, *Benth. and Hook. f.*, 10.
Pongamia, Vent., 331.
 glabra, *Vent.*, 331.
Pterocarpus, Linn., 265.
 dalbergioides, *Roxb.*, 277.
 indicus, *Willd.*, 292.
 macrocarpus, *Kurz*, 287.
 Marsupium, *Roxb.*, 266.
 santalinus, *Linn. f.*, 272.
Pterospermum, Schreber, 160.
 acerifolium, *Willd.*, 160.
 semisagittatum, *Ham.*, 160.

RHAMNACEAE, 211.
Rhus, Linn., 235.
 Cotinus, *Linn.*, 235.
 parviflora, *Roxb.*, 235.
 punjabensis, *J. L. Stewart*, 235.
 succedanea, *Linn.*, 235.
Robinia, Linn., 332.
 Pseudacacia, *Linn.*, 332.
RUTACEAE, 166.

Saccopetalum, Bennett, 9.
 tomentosum, *Hook. f. and Th.*, 9.
Sandoricum, Cav., 204.
 indicum, *Cav.*, 204.
SAPINDACEAE, 221.
Sapindus, Linn., 232.
 detergens, *Roxb.*, 232.
 emarginatus. Vahl, 233.
 laurifolius, *Vahl*, 233.
 Mukorossi, Gaertn., 232.
 trifoliatus, Linn., 233.
Schima, Reinw., 29.
 Wallichii, *Choisy*, 29.

Schleichera, Willd., 229.
 trijuga, *Willd.*, 229.
Semecarpus, Linn., 236.
 Anacardium, *Linn. f.*, 236.
Shorea, Roxb., 55.
 assamica, *Dyer*, 133.
 laccifera, Heyne, 133.
 obtusa, *Wall.*, 132.
 robusta, *Gaertn. f.*, 55.
 siamensis, Miq., 53.
 Talura, *Roxb.*, 133.
 Tumbuggaia, *Roxb.*, 130.
SIMARUBACEAE, 171.
Skimmia laureola, *Sieb. and Zucc.*, 166.
Soymida, Adr. Juss., 187.
 febrifuga, *Adr. Juss.*, 187
Spatholobus Roxburghii, *Bth.*, 250.
Spondias, Linn., 246.
 mangifera, *Willd.*, 246.
Sterculia, Linn., 151.
 alata, *Roxb.*, 152.
 foetida, *Linn.*, 153.
 Haynii, Bedd., 152.
 urens, *Roxb.*, 151.
 villosa, *Roxb.*, 152.
STERCULIACEAE, 151.
Swietenia, Linn., 205.
 Chloroxylon, Roxb., 200.
 febrifuga, Roxb., 187.
 macrophylla, *King*, 208.
 Mahagoni, *Linn.*, 205.

TAMARICACEAE, 15.
Tamarix, Linn., 15.
 articulata, *Vahl*, 18.
 dioica, *Roxb.*, 18.
 ericoides, *Rottl.*, 15.
 gallica, *Linn.*, 15.
 indica, *Roxb.*, 15.
 orientalis, Linn., 18.
 Troupii, *Hole*, 16.
Taraktogenos, Hassk., 15.
 Kurzii, *King*, 15.
TERNSTROEMIACEAE, 29.
Thespesia, Correa, 150.
 populnea, *Corr.*, 150.
TILIACEAE, 162.
Toddalia aculeata, *Pers.*, 166.

Uvaria villosa, Roxb., 8.

Vateria, Linn., 134.
 indica, *Linn.*, 134.
Vatica laccifera, W. and A., 133.
Vatica Roxburghiana, *Blume*, 31.
Vatica Tumbuggaia, W. and A., 130.

Xylocarpus Granatum, Willd., 186.

Zizyphus, Juss., 211.
 Jujuba, *Lam.*, 211.
 latifolia, Roxb., 221.
 microphylla, Roxb., 220.
 Napeca, Roxb., 220.
 nummularia, *W. and A.*, 220.
 Oenoplia, *Mill.*, 220.
 rugosa, *Lam.*, 221.
 vulgaris, *Lam.*, 220.
 Xylopyrus, *Willd.*, 215.